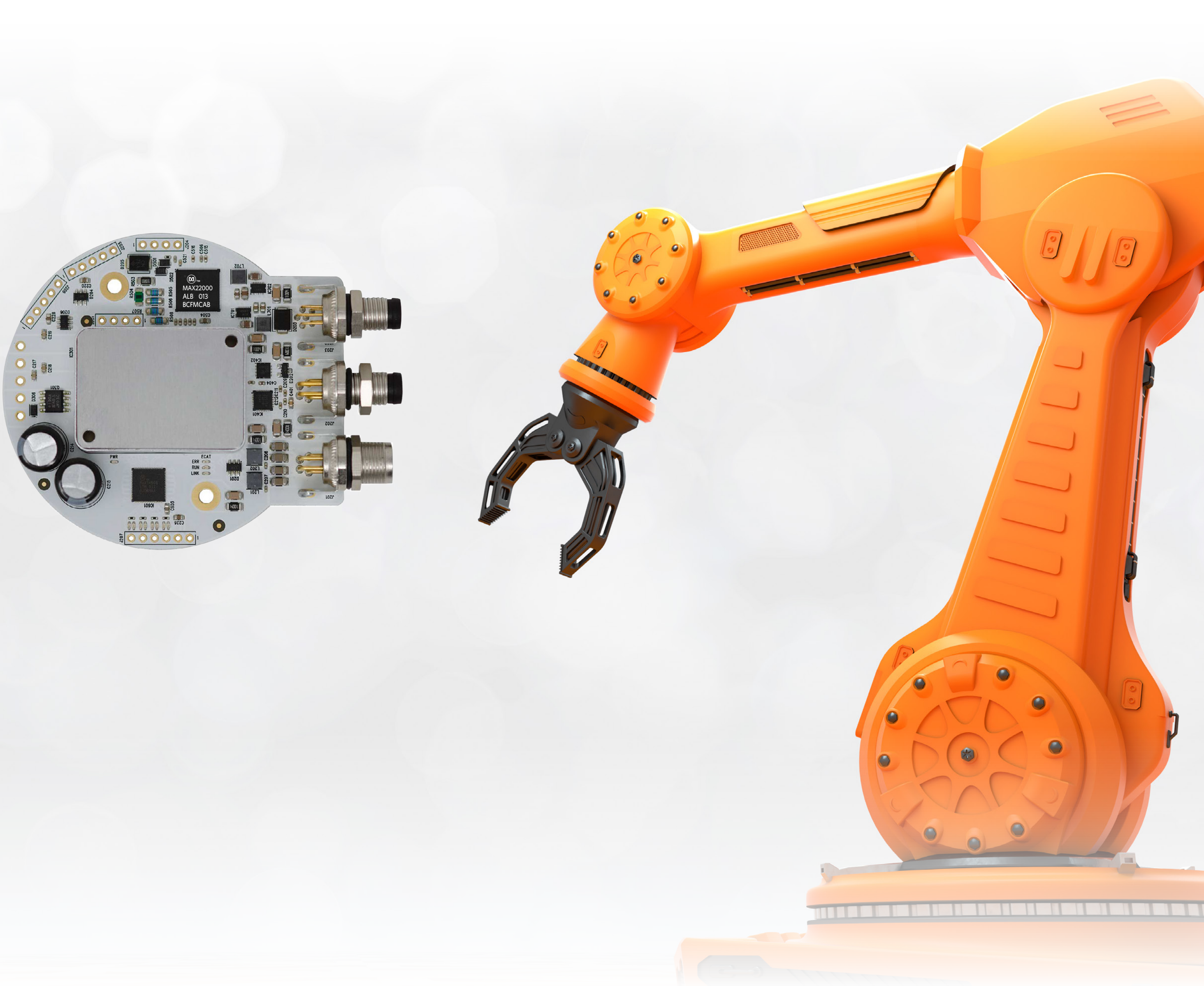
INDUSTRIAL IO HANDBOOK

First Edition



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Forward

As factories strive to boost productivity and improve operational costs, the demand to deliver new technology that empowers intelligence at the edge is increasing. At Maxim Integrated®, we define "the edge" as the place where a machine meets or interacts with the real world.

While digital and analog IO continue to be the workhorse on the factory floor, Maxim Integrated understood at an early stage that the key to delivering intelligence to the edge would be the availability of software-configurable universal IO solutions that could be configured "on-the-fly" as production requirements change.

Software-configurable digital and analog IO solutions afford automation engineers and technicians the convenience of providing a universal IO port that can be commissioned remotely. Comparable with the benefits provided by our IO-Link® solutions, this new class of digital and analog software-configurable IO products simplifies a factory's wire-marshalling burden and provides the flexibility to physically connect a choice of digital or analog IO sensors or actuators to any unassigned IO port. This software-configurable technology is more cost-effective because it increases channel density on the factory floor.

In this handbook, we present our complete portfolio of industrial digital IO, analog IO, configurable IO, and complementary ICs. You will discover that they combine unsurpassed levels of robustness with the most advanced diagnostic features. We also include numerous reference designs that provide a template to quickly bring your products to market. No matter what your industrial IO requirement, we are confident that you will find the solution you are looking for. After all, solving technical problems is what we do best at Maxim Integrated.

Jeff DeAngelis,
Vice-President
Industrial & Healthcare Business Unit
Maxim Integrated

Part 1: Digital IO

Digital input (DI) and digital output (DO) modules for automated industrial controllers have, historically, used discrete components in their design. Industry 4.0, the next revolution in the way factories run, will demand not only cloud control, but also faster throughput to maximize efficiency and profits. With the added requirement for more diagnostic features to increase uptime, all in a significantly smaller form factor with lower power, the challenge ahead becomes clear. The first step in the journey is for designers to become educated on the available integrated devices on the market, so that DI and DO modules can ultimately realize their performance potential. In this document, we present our current portfolio of integrated digital IO products and show how they can better rise to the challenge of Industry 4.0 demands compared to the traditional digital IO design approach.

Digital Input

Digital input cards are located within an industrial input/output (IO) module. A DI card receives signals from multiple binary sensors or switches located throughout the factory floor, monitoring parameters such as liquid levels, proximity of objects, or the status of an on/off pushbutton switch on a piece of equipment. An input signal of 0V is recognized as a logical ‘0’ (or off) whereas a voltage level of 24V (typically) is a logical ‘1’ (or on). The purpose of the DI is to receive the signal from the sensor or switch, translate it to a lower logic level, and send it to a programmable logic controller (PLC) to perform an appropriate action (e.g., sending an output signal) depending on the status of the input. The requirement for galvanic isolation between the high voltages of the factory floor and the lower logic levels of the controller, as well as the need for high integration of channels in ever shrinking enclosures complicates what might otherwise appear to be a reasonably straightforward task.

Digital Input Types

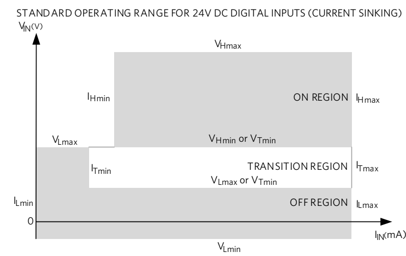
The IEC 61131-2 standard governs the input threshold and current requirements for sinking DI circuits in industrial applications and defines three types of DI circuits for industrial applications:

Type 1: Electromechanical circuits

Type 2: Discrete, high-current semiconductor circuits

Type 3: Low-power integrated semiconductor circuits

The differences between the DI types are primarily the voltage thresholds and current limits. Additionally, DI circuits are typically used in one of two configurations: positive logic (sinking inputs and sourcing outputs), negative logic (sourcing inputs and sinking outputs). The IEC 61131-2 thresholds for 24V and 48V (DC and AC) sinking inputs are shown in **Figure 1**.



Type of Limit	Type 1 Limits						Type 2 Limits						Type 3 Limits					
	Off Region		Transition		On Region		Off Region		Transition		On Region		Off Region		Transition		On Region	
	V_L (V)	I_L (mA)	V_T (V)	I_T (mA)	V_H (V)	I_H (mA)	V_L (V)	I_L (mA)	V_T (V)	I_T (mA)	V_H (V)	I_H (mA)	V_L (V)	I_L (mA)	V_T (V)	I_T (mA)	V_H (V)	I_H (mA)
Max	15/5	15	15	15	30	15	11/5	30	11	30	30	30	11/5	15	11	15	30	15
Min	-3	ND	5	0.5	15	2	-3	ND	5	2	11	6	-3	ND	5	1.5	11	2

ND = NOT DEFINED

Figure 1. Digital Input Characteristics According to IEC 61131-2

Discrete Single-Channel Digital Output

A single DI channel was traditionally implemented using discrete components. The simplified circuit in **Figure 2** is based on a resistor-divider network with an optocoupler for isolation. The 24V DC input voltage is divided down to an appropriate level to drive the optocoupler, which signals the input logic level to the PLC.

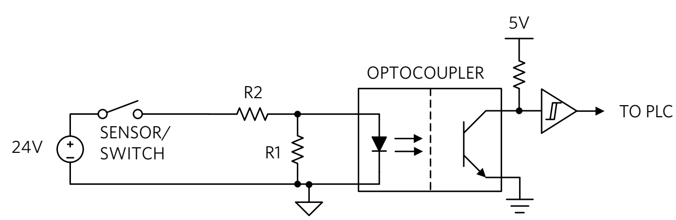


Figure 2. Discrete DI with Basic Current Limiting

Although inexpensive and easy to design, a major disadvantage of this approach is that power consumption is high (up to 10mA, depending on resistor values) and varies proportionally to the input voltage level. While it is possible to build a discrete current-limiting circuit, it requires several components (increasing cost and area) and consumes current well above the ideal 2mA level for a Type 3 DI as specified in the IEC 61131-2 standard. Clearly, for reasons of size and power consumption (with associated heat dissipation), a discrete circuit configuration is not suitable for high levels of integration into a small form-factor, high-density IO module.

Single-Channel Integrated Digital Input

An alternative to a discrete circuit is to use a single-channel integrated solution such as the **MAX22191**. This current-limiting, parasitically powered DI is also an IEC 61131-2-compliant, industrial DI IC that translates a 24V digital industrial input into a 2.3mA (typical) current for driving optical isolators. Voltage thresholds and current levels are also compliant with Type 1 and Type 3 inputs and support both current-sink and current-source applications. With the addition of external resistors, it can be made compliant with 48V or AC inputs. Operating power is derived from an external power source or, alternatively, from the input signal itself, eliminating the need for an external field-side power supply and therefore simplifying board wiring. A 250ns (max) fast response time makes it ideal for high-speed inputs. Additionally, a CMOS-compatible test input is available for safety diagnostics. Robust operation supports harsh industrial systems with input signals ranging from -60V to +60V. Integrated thermal shutdown further protects the device when V_{CC} is present. It is available in a small, 6-lead SOT23 package, suitable for individually channel-isolated modules.

Figure 3 shows an application circuit where the MAX22191 parasitically powers itself, an optical isolator, and an external LED for status information, making it the lowest power digital input solution available. When the input voltage (V_{IN}) exceeds the input-high threshold, the output sources 2.3mA (typical) current and offers a voltage compliance that is enough to drive both an external status LED and an optical isolator. When the input voltage drops below the input-low threshold, the output current is cut off and the LED is thus turned off, and the optical isolator is off.

Multi-Channel Digital Inputs

While a single-channel integrated IC is an improvement on the discrete implementation, even higher levels of integration are required to implement 8, 16, 32, or even 64 DI channels, which are common in the latest IO modules. However, multi-channel DI ICs bring their own challenges. The increased number of channels requires designers to think about how they wish to interface the channel to the controller – parallel or serial? While a serial data stream means fewer pins to isolate, it also means the isolator must function at the appropriate data rate for the bit stream. It must be scalable and requires some form of error detection to verify the integrity of the data stream during communication with the controller. On the other hand, a parallel data stream may appear to be simpler, but it requires a larger isolation IC for the multiple data channels. Maxim has a complete portfolio of multi-channel DI ICs and companion products to address the many and varying challenges of digital IO module design.

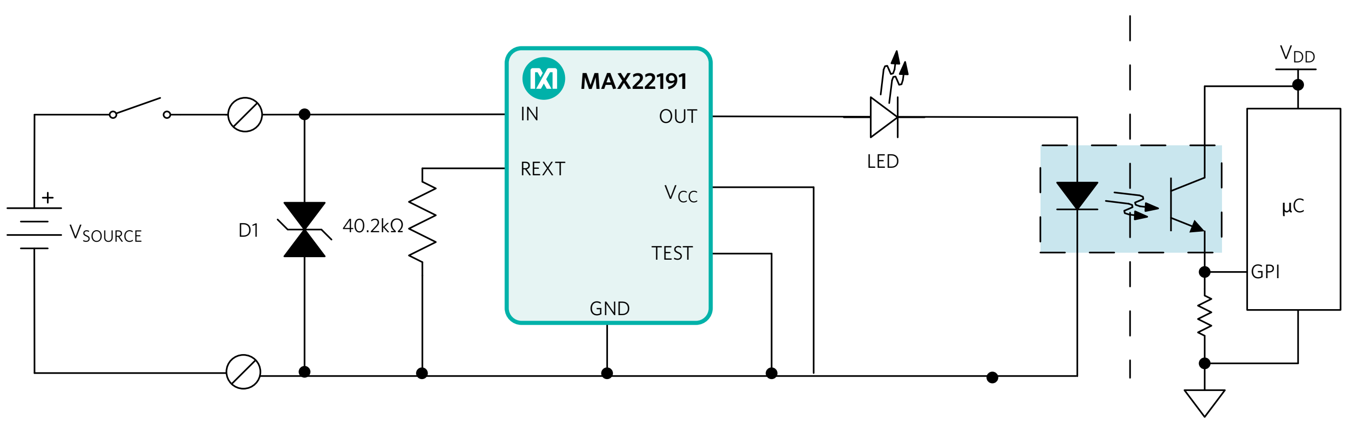


Figure 3. MAX22191 Current-Sinking Circuit with Status/Indicator LED

Octal Digital Input with Serial Output

The **MAX22190** and **MAX22199** octal digital input ICs translate eight, 24V current-sinking, industrial inputs into a serialized SPI-compatible output that interfaces with 3V to 5.5V logic. Both DI devices can operate either as eight Type 1/Type 3 digital inputs or four Type 2 digital inputs. Robust internal ESD structures mean they can withstand up to 1A surge current and line-to-ground voltage surge up to 2kV (with external resistors but with no requirement for an external TVS). Energy-less, field-side LED drivers can be used to indicate input status. Where more than eight channels are required, multiple devices can be daisy-chained together as shown in **Figure 4.**

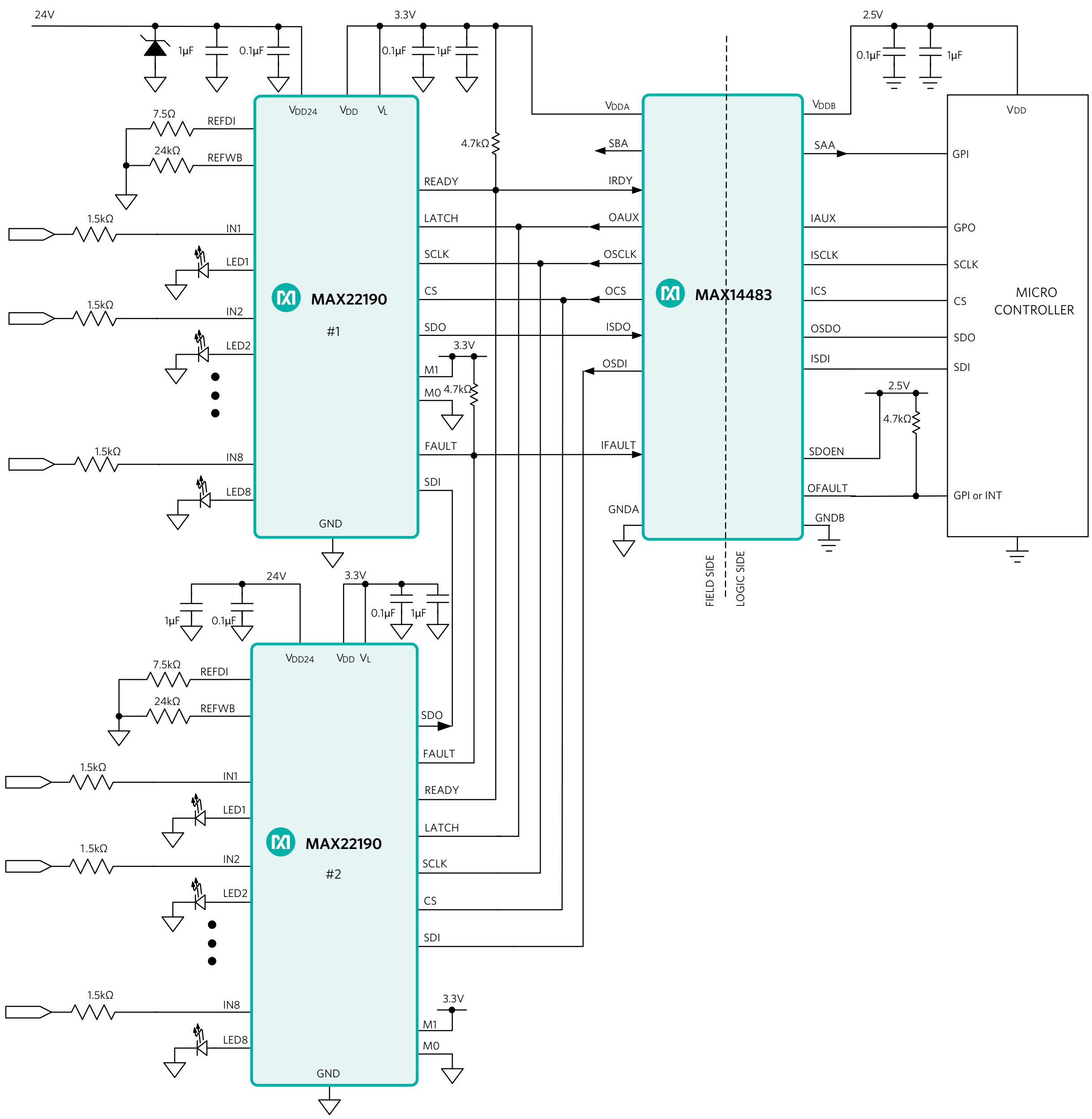


Figure 4. 16-Channel Isolated Type 1/Type 3 DI, SPI Daisy Chain

Both the MAX22190 and MAX22199 have a 4-pin SPI interface and use a LATCH input to synchronize input data across multiple parallel devices. When powered by the field supply (7V to 65V, but typically 24V), the device generates a 3.3V output from an integrated LDO regulator, which can provide up to 25mA of current for external loads (such as a digital isolator). Alternatively, the device can be directly powered from a 3.0V to 5.5V field side supply. This has the advantage of further reducing power dissipation since the internal LDO is disabled. For flexibility, the SPI interface operates at 3.3V or 5V logic levels. For robust operation in industrial environments, each input channel includes a programmable glitch filter, the delay on which can be independently programmed to one of eight values between 50µs and 20ms or bypassed. **Figure 5** illustrates how two inputs can be connected in parallel to configure the MAX22190 (or MAX22199) as four Type 2 DIs with the increased current limits set by the REFDI resistor as required.

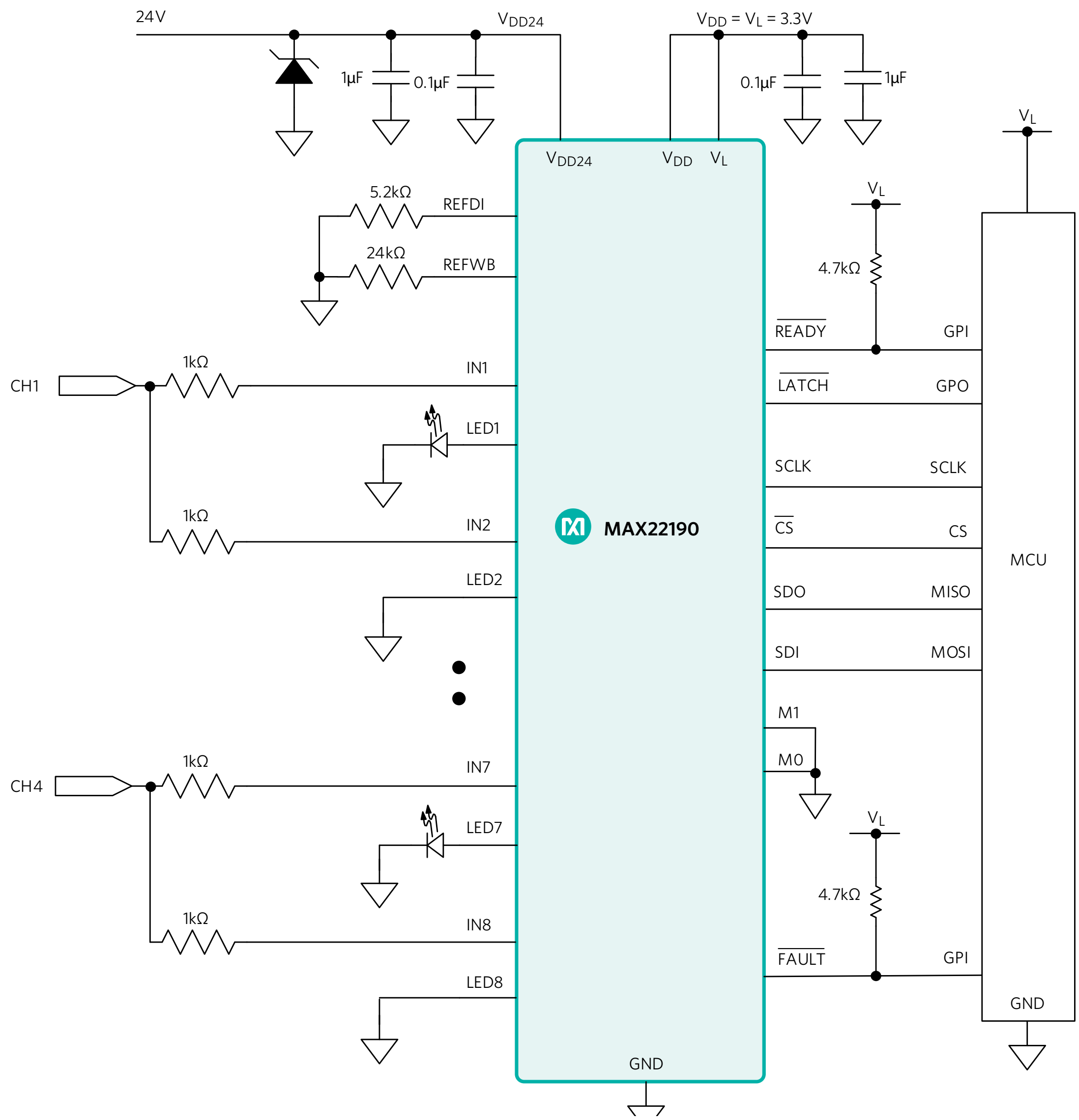


Figure 5. The MAX22190 Configured as Four Type 2 Digital Inputs

Diagnostics

The MAX22190 provides additional fault-detection diagnostic features. This allows verification of field wiring for sensors (such as proximity switches) using a second threshold detector on each input. When the wire-break detect feature is enabled, a FAULT output is asserted, and a register flag is set if the input current drops below the wire-break threshold for more than 20ms. Other diagnostics that assert the FAULT output include: overtemperature, low 24V field supply, 24V field supply missing, and SPI and CRC communication error.

Octal Digital Input with Serial Output and Integrated Isolation

An alternative to the MAX22190 is the **MAX22192**, which provides the added benefit of integrated galvanic isolation of the SPI interface. When powered by the field supply (7V to 65V), a 3.3V output is generated from an integrated LDO regulator, capable of providing up to 25mA of current for external loads. Alternatively, the field side of the MAX22192 can be powered from a 3.0V to 5.5V supply with the logic-side powered from a single 1.71V to 5.5V supply to interface with 1.8V, 3.3V, or 5V logic levels. As shown in **Figure 6**, applications requiring more than eight inputs, can daisy-chain the MAX22190 with the MAX22192 which then provides an isolated path to the microcontroller.

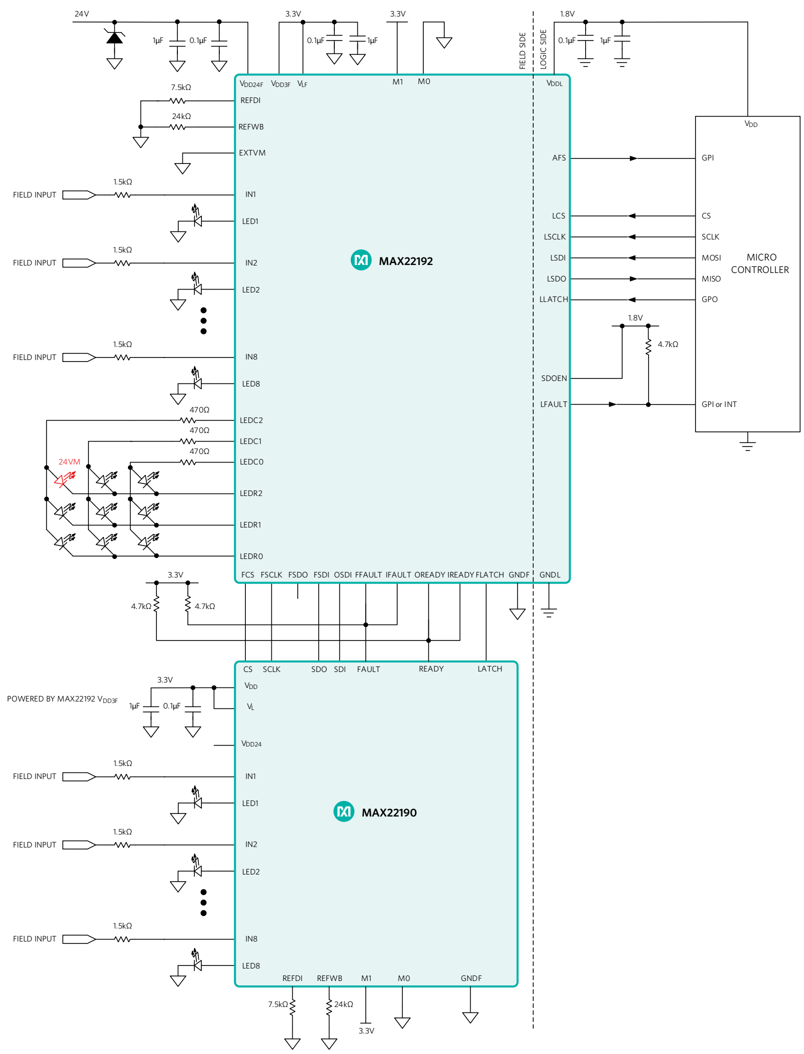


Figure 6. 16-Channel Isolated DI Using MAX22190 and MAX22192

Octal Digital Input with Parallel Output

The **MAX22195** (**Figure 7**) translates eight 24V industrial digital inputs into eight CMOS-compatible, parallel outputs with a propagation delay from input-to-output of less than 300ns on all channels. High-accuracy current-limiters on each input greatly reduce power dissipation compared to traditional resistor-divider inputs while maintaining compliance with the IEC 61131-2 standard. A current-setting resistor allows configuration for eight Type 1/Type 3 inputs or four Type 2 inputs while additional, energy-less field-side LED drivers meet the indicator light requirement of IEC 61131-2, with no additional power dissipation. An internal 3.3V LDO accepts a field supply voltage from 7V to 65V, which in addition to providing device power, can supply up to 25mA of current to power digital isolators and other field-side circuits. Alternatively, the MAX22195 can be powered from a separate 3.0V to 5.5V supply.

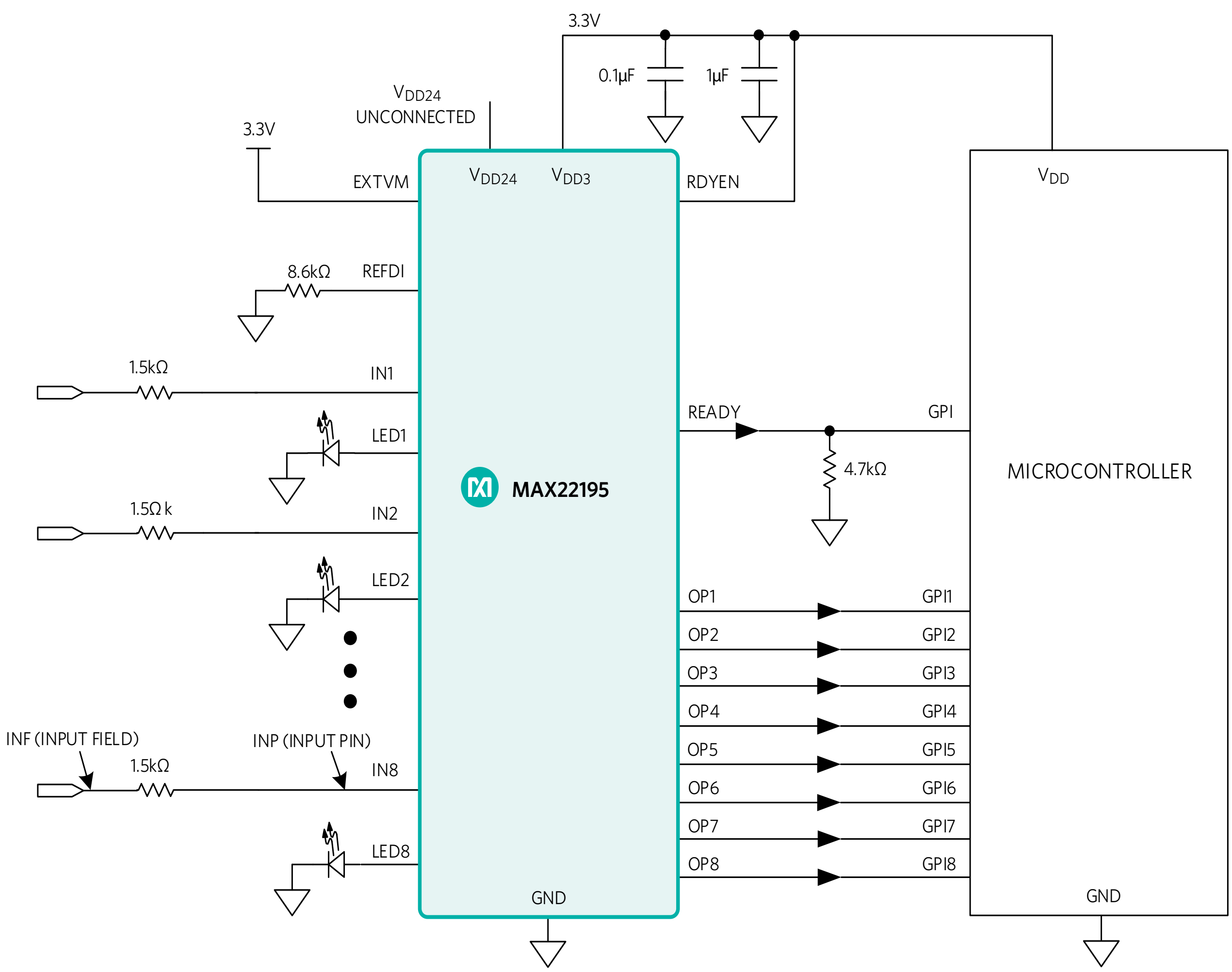


Figure 7. MAX22195 Octal DI with Parallel Interface

Digital Input Summary

The main features of Maxim's portfolio of digital inputs are summarized in **Table 1**.

Table 1. Summary of Digital Input ICs

Part Number	No. of Channels	Isolation	IEC 61131-2 Compliant	Output Interface
MAX22191	1	External Optocoupler	1,3	Current or Voltage
MAX22190	8	External Isolator IC	1,2,3	Serial Voltage
MAX22199	8	External Isolator IC	1,2,3	Serial Voltage
MAX22192	8	Internal	1,2,3	Serial Voltage
MAX22195	8	External Isolator IC	1,2,3	Parallel Voltage
MAX22196	8	External Isolator IC	1,2,3	Serial Voltage

Digital Output

The term Digital Output is used to describe an electronic circuit used to switch on and off industrial control devices such as relays, motor actuators, open/close valves, solenoids, and indicators. DOs produce signals that can range from 0V (off) to 60V (on), but typically vary between 0V and 24V. High voltage levels are required to ensure that the digital state can be reliably determined by a receiver after the signal has traversed a long cable within an electrically noisy environment, while high current levels are required to quickly turn on or off heavy inductive (and sometimes also capacitive) loads. **Figure 8** shows a block diagram for a typical DO implementation.

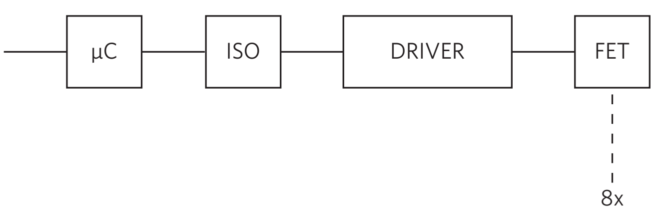


Figure 8. Simplified Model of Typical Digital Output

While conceptually simple, real-world implementations of DOs vary considerably. Integrated driver (or controller) ICs, developed to replace old mechanical relays, are commonly used to switch (sometimes multiple) discrete n-channel power FETs that drive the load. The FET/driver configuration depends on the nature of the load — a ground connected load is switched using a high-side (HS) arrangement whereas a supply connected load is switched using a low-side (LS) setup. Floating loads are switched using a combination of both, commonly referred to as push-pull (PP). Advances in semiconductor technology now allow the power FETs to be integrated into the same package as the driver, effectively providing a fully integrated DO suitable for many (but not all) applications. There are relative merits to both approaches. Integrated FETs save space but using external FETs offers greater flexibility for voltage and current blocking. DO ICs now commonly provide a range of additional diagnostic and safety features including undervoltage lockout (UVLO) to ensure supply voltage levels are present for proper operation and a temperature shutdown mode that prevents damage in the event of an unintended short-circuit or overcurrent event. Maxim provides a comprehensive portfolio of DO devices including controllers, high-side, low-side and push-pull ICs.

High-Side Switch Controller with Current Limiting

The **MAX14922** (**Figure 9**) is a high-side, n-channel FET controller suitable for switching ground connected loads in industrial applications. This IC, which operates from a 9V to 70V supply range, controls the gate voltage of an external n-channel MOSFET. Fast inductive load turn-off can be achieved by using a high-voltage transient voltage suppression (TVS) diode that also provides voltage clamping up to a maximum of -70V. The load current can be limited to a predefined value using a sense resistor and external FET overload protection is provided using an auto-retry timing feature (defined by a user-selected capacitor C_{BLANK} connected to the t_{BLANK} input pin). This controller also includes an on-chip comparator that can be used to monitor the high-side switch output or the supply input voltage. The MAX14922 has an integrated charge pump that enables high-speed switching (20kHz to 50kHz) when using FETs with low on-resistance (R_{ON}).

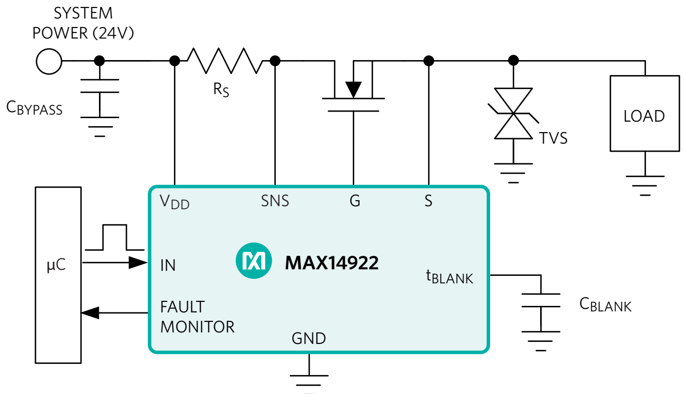


Figure 9. MAX14922 High-Side Switch Controller

Octal High-Side Switch with Diagnostics

The **MAX14915** provides eight high-side switches (with a maximum R_{ON} of 250mΩ) specified to deliver up to 700mA continuous current per channel. It has an SPI interface with a built-in chip-addressing decoder to allow communication with multiple ICs (**Figure 10**) using a common SPI chip select (CS). The SPI interface also provides flexibility for global (and per-channel) configuration and diagnostics, including overvoltage and undervoltage detection, open wire/load detection, overload and current limiting reporting and for reporting thermal conditions. It can also detect open-wire and open-load conditions with switches in either state. The MAX14915 provides LED drivers that can be used to indicate the fault, status, and supply undervoltage conditions for each channel. Internal active clamps allow for fast turn-off of inductive loads while integrated line-to-ground and line-to-line surge protection require only a single TVS diode on V_{DD}.

Two companion parts, the **MAX14916** allows output pairs to be connected in a quad configuration, providing up to 2A per-channel drive current, while the **MAX14917** provides the same electrical output characteristics as the MAX14915, but with fewer diagnostic features.

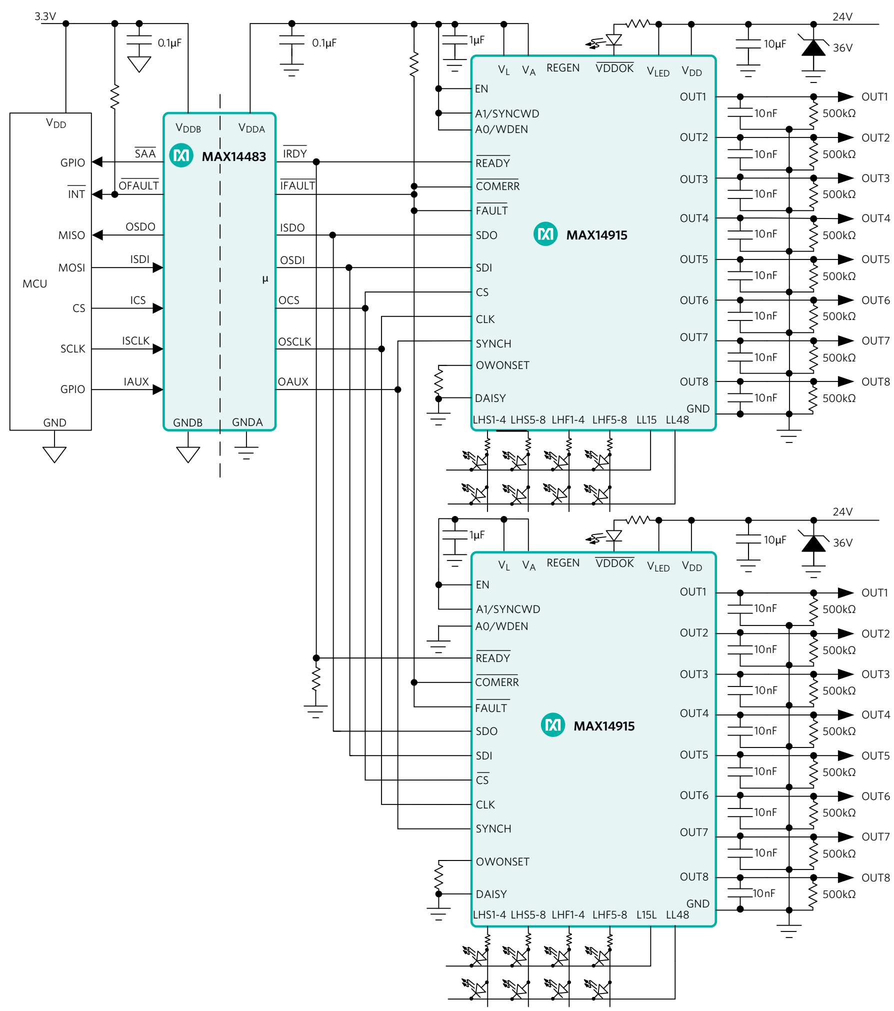


Figure 10. 16-Channel Isolated DO Application Using a 6-Channel Digital Isolator

Quad-Channel Low-Side Switch

The **MAX14919** is a quad-channel low-side switch with 140mΩ typical on-resistance (R_{ON}) per channel. It allows resistor-settable current limiting guaranteed to provide accurate operating currents in the range of 100mA to 800mA. It also provides a 2x inrush load-current option to supply loads that draw large activation or inrush currents. Outputs can be connected in parallel to achieve even higher load currents. The four switches are pin controlled for simple and fast switching, at rates of up to 200kHz. The MAX14919 features reverse-current detection (**Figure 11**) to prevent damage against load-supply miswiring faults (this feature is disabled in MAX14919A). For robust performance, it also includes integrated ±1kV/42Ω surge protection without any external component.

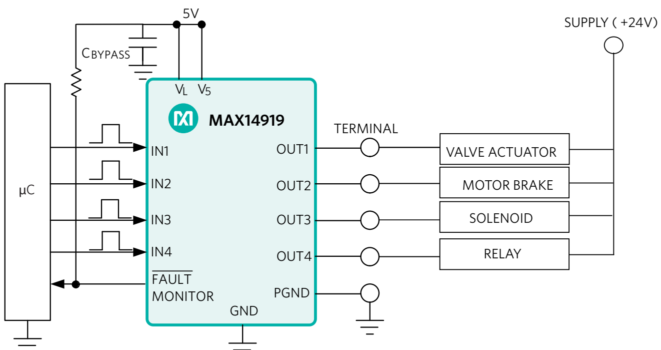


Figure 11. MAX14919 Low-Side Switch Typical Application

Octal High-Side Switch/Push-Pull Driver

The **MAX14912** and **MAX14913** (**Figure 12**) integrate eight, 640mA smart high-side switches that can also be configured as high-side switches or push-pull drivers for high-speed switching. The propagation delay from input to switching of the high-side/low-side drivers is 1µs (max). Each high-side driver has a low on-resistance of 230mΩ (max) at 500mA load current at T_A = +125°C. The device is configured and controlled either through multiple pins or the SPI interface. The SPI interface is daisy-chainable, which allows efficient cascading of multiple devices. The MAX14912 allows configuration through either SPI mode or parallel mode, while the MAX14913 supports configuration through SPI mode only. Open-load detection in high-side mode detects open-wire conditions in the switch on/off states, and LED drivers provide indication of per-channel fault and status conditions. Internal active clamps quickly accelerate the shutdown of inductive loads in high-side mode. During turn-off of inductive loads by the high-side switch, the kickback voltage generated by the inductance is clamped to a voltage of -56V (typical) relative to V_{DD}. This large inductance energy is dissipated in the device through the voltage clamp. These DO ICs also feature safe demagnetization (SafeDemag™), which allows inductive loads of any value to be switched off. In high-side mode, there is no limitation of the inductive load that can be switched by the outputs.

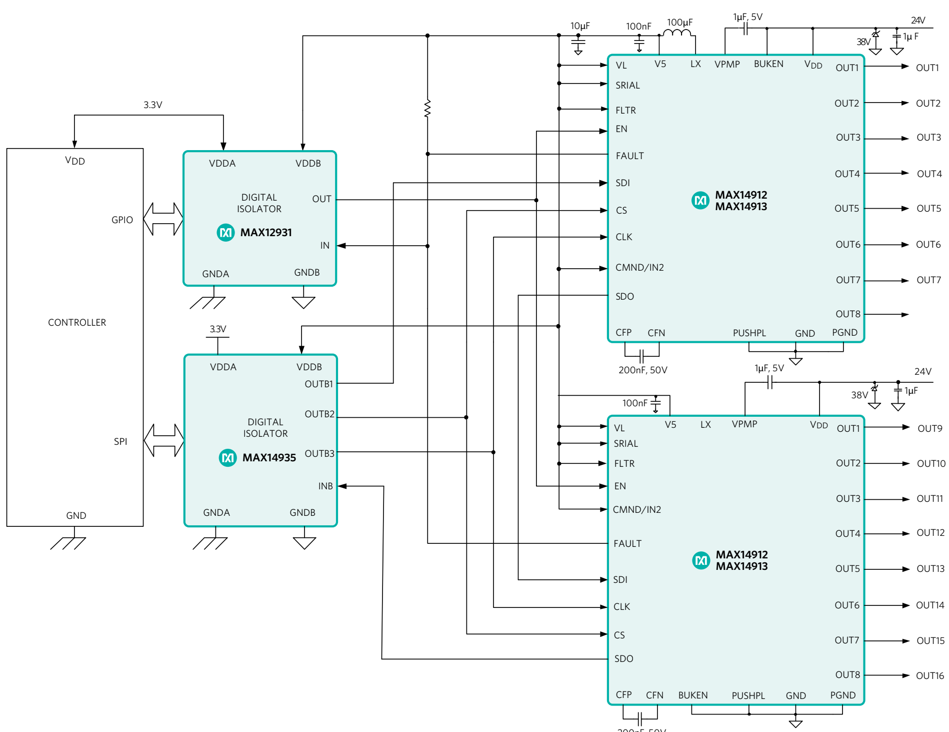


Figure 12. MAX14912/MAX14913 Typical Application Circuit

Digital Output Summary

Maxim's portfolio of Digital Output ICs is summarized in **Table 2**.

Table 2. Summary of Digital Output ICs

Part Number	No. of Outputs	Configuration	R_{ON} (mΩ)	I_{OUT} (A)	Demag Feature
MAX14900E	8	HS	165	0.85	None
MAX14912/**MAX14913**	8	HS or PP	230	0.5	Safe
MAX14915/**MAX14917**	8	HS	250	0.7	Fast
MAX14916	4 or 8	HS	250	2.4 (quad channel) or 1.1 (octal channel)	Fast
MAX14919/**MAX14919A**	4	LS	300	0.8	Fast
MAX14922	1	External FET	—	—	N/A

Configurable Digital IO

High-Side Switch with Push-Pull Driver and Digital Input Configuration

The **MAX14914** (**Figure 13**) is a single-channel high-side/push-pull DO driver that can also be configured to operate as an IEC 61131-2-compliant DI (Type 1, Type 2, or Type 3). Specified for operation with supplies up to 40V, the high-side switch current is resistor-settable from 135mA (min) to 1.3A (min) with a typical R_{ON} of 120mΩ. It also provides optional push-pull operation to drive cables and for fast discharge of load capacitance. Output voltage is monitored for safety applications. The **MAX14914A** is a low-leakage version of the MAX14914, designed to work together with the **MAX22000** industrial configurable analog IO device (see part 2 of this design guide), while the **MAX14914B** features a high-side switch overcurrent indication. A summary of output driver limiting features for these ICs is shown in **Table 3**.

Table 3. Output Driver Limiting Features

	DOI Overvoltage (OV_VDD)	DOI Overcurrent (OV_CURR)	Low DOI Leakage ($V_L < V_{L\_POR}$)
MAX14914	Yes	No	No
MAX14914A	Yes	No	Yes
MAX14914B	No	Yes	No

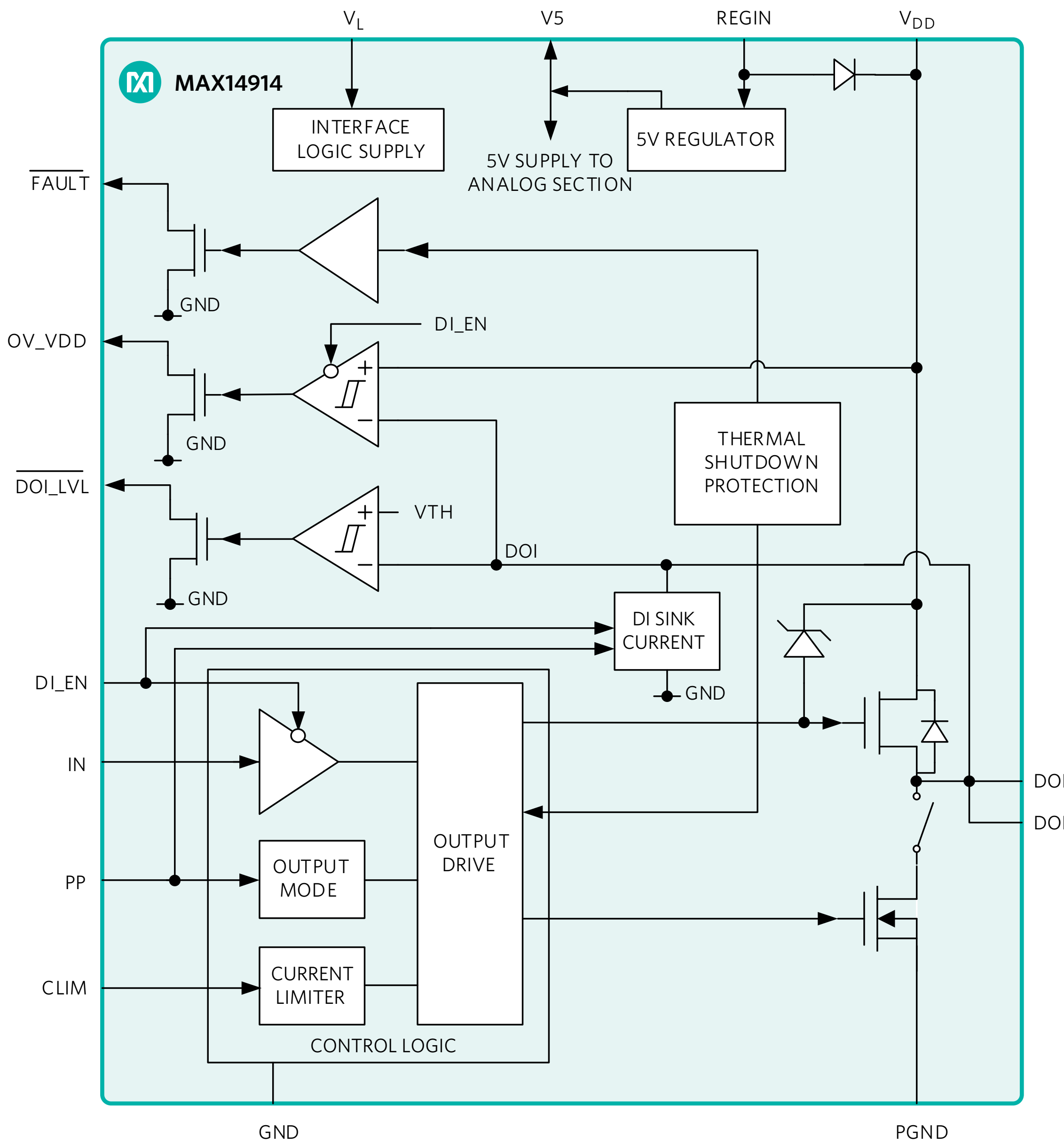


Figure 13. MAX14914 Functional Diagram

Quad-Channel Industrial Digital Output/Digital Input

The **MAX14906** (**Figure 14**) is an IEC 61131-2-compliant, high-speed, four-channel IC that can be configured on a per-channel basis as either a high-side switch, push-pull driver, or a Type 1 and 3, or Type 2 digital input. Specified for operation with a supply voltage up to 40V, it is tolerant to voltages up to 65V. The high-side switch current limiting is settable from 130mA to 1.2A with the option of 2x load inrush current. The high-side driver has a typical R_{ON} of 120mΩ at 25°C. It also provides optional push-pull operation to drive cables and for fast discharge of load capacitance. For digital input operation, current sinks for 2.3mA (Type 1 and 3) or 7mA (Type 2) are provided. The SPI interface has a built-in chip addressing decoder, allowing communication with multiple ICs using a shared SPI via a common chip select (CS). The SPI interface provides flexibility for global and per-channel configuration and diagnostics, including supply overvoltage and undervoltage detection, wire-break or open-wire detection, thermal overload and current-limit reporting. For high-speed operation, the digital input and output states can be monitored and changed directly using pins. LED drivers can be used to provide indication of per-channel fault, status, and supply undervoltage conditions. Internal active clamps allow for fast turnoff of inductive loads while integrated line-to-ground and line-to-line surge protection requires only a single TVS on V_{DD}.

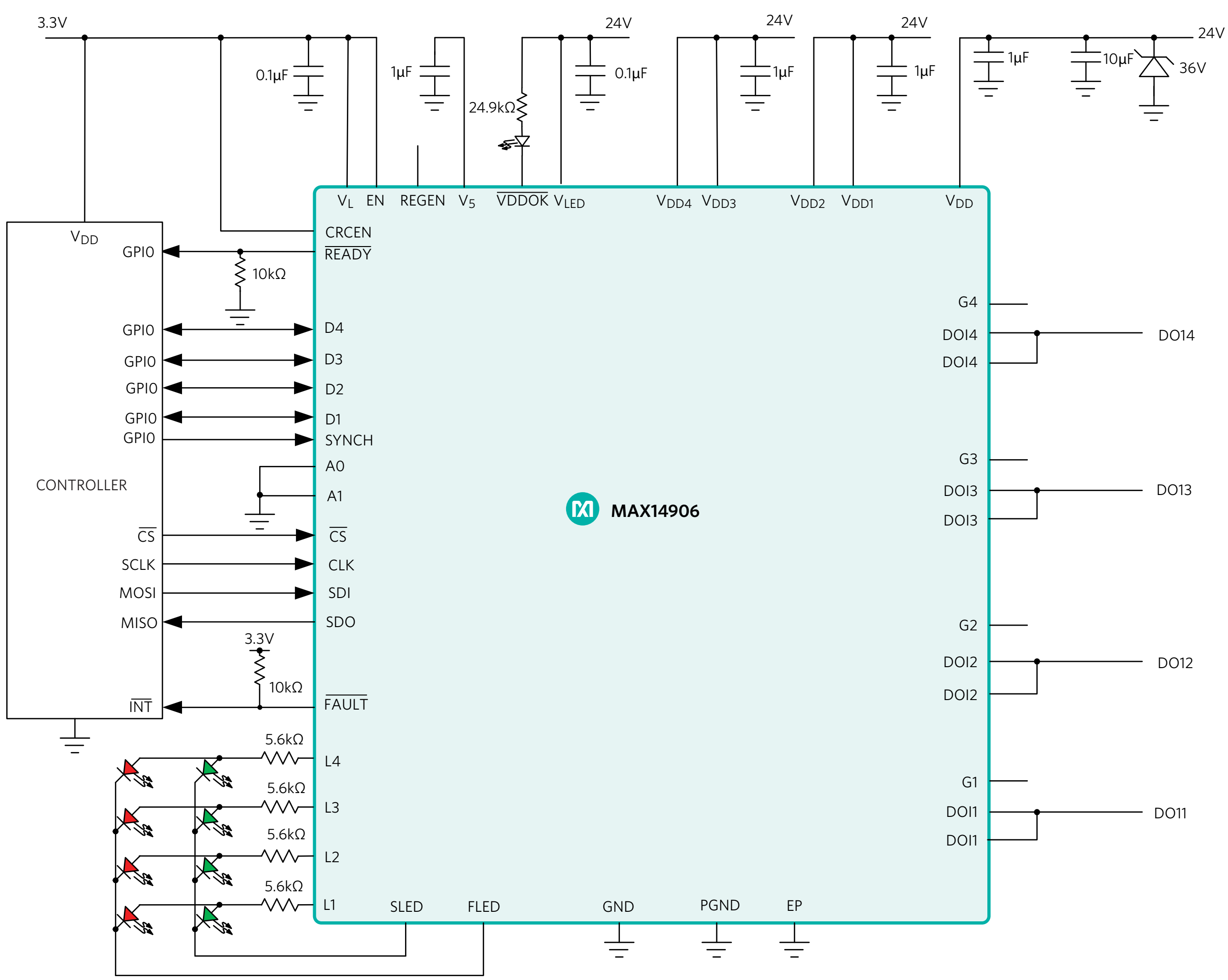


Figure 14. MAX14906 Typical Application Circuit

Configurable Digital IO Summary

Table 4. Summary of Configurable Digital IO ICs

Part Number	No. of Channels	Digital Input (Type 1,3 vs. Type 2)	Output Type	Output Current	R_{ON} (mΩ) typ
MAX14014	1	Pin Selectable	HS or PP	135mA to 1.3A	120
MAX14914A	1	Pin Selectable	HS or PP	135mA to 1.3A	120
MAX14914B	1	Pin Selectable	HS or PP	135mA to 1.3A	120
MAX14906	4	Software Settable	HS or PP	130mA to 1.2A	120

DIGITAL IO COMPANION ICs

6-Channel SPI Digital Isolator

The **MAX14483** is a general-purpose SPI isolator with extra channels for control signals that are optimized for interfacing to the MAX22190 but are also compatible with other SPI devices such as the MAX14915 and MAX14906. The SDO channel's tri-state control allows a single MAX14483 to isolate multiple SPI devices (**Figure 15**). To simplify system design, an open-drain FAULT output can be wire-ORed with error outputs from other devices. In addition, an auxiliary channel is available for passing timing or control signals from the master side to the slave side. Power monitors are provided for both power domains that signal when the opposite side of the isolator is ready for operation. Independent 1.71V to 5.5V supplies also make the device suitable for use as a level translator. With an isolation rating of 3.75kV$_{RMS}$ (for 60s), it is available in a 20-pin SSOP package with 5.5mm of creepage and clearance. The package material has a minimum comparative tracking index (CTI) of 400, which gives it a group II rating in creepage tables. Figure 16 illustrates how the MAX14483 can be used in daisy-chain mode to drive two 8-channel MAX14915 DO drivers.

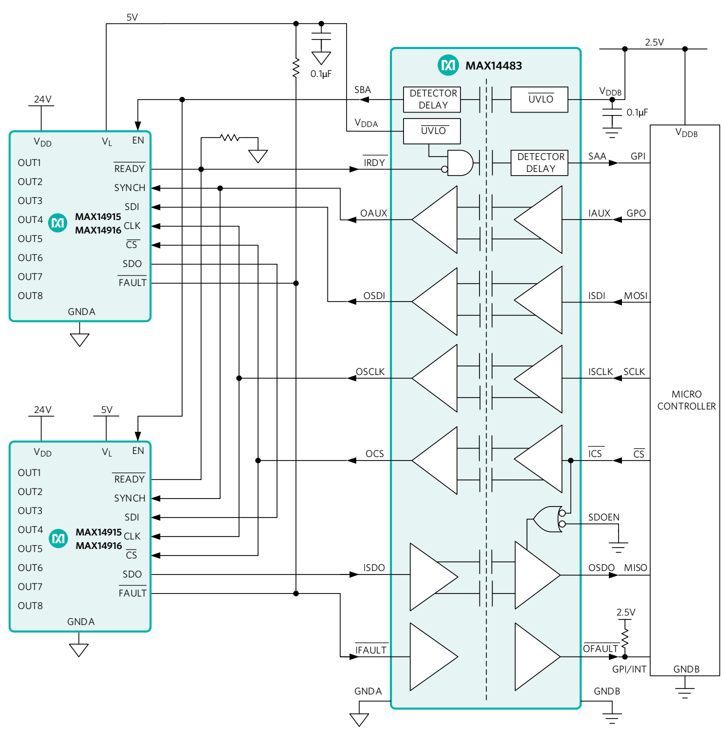


Figure 15. MAX14483 SPI Isolator Application Circuit

Reinforced Four-Channel Digital Isolators

The **MAX22444**, **MAX22445**, and **MAX22446** are reinforced, fast, low-power, 4-channel digital galvanic isolators. These reinforced isolators provide a withstand voltage rating of $5kV_{RMS}$ for 60s. All possible unidirectional channel configurations are supported to accommodate any 4-channel design, including SPI, RS-485, and digital I/O applications (**Figure 16**). Output enable for the A side of the MAX22445R/S/U/V is active-low, making it ideal for isolating a port on a shared SPI bus since the $\overline{CS}$ signal can directly enable the MISO signal on the isolator. All other output enables in this family of isolators are active-high. All channels on the MAX22444–MAX22446M/N are always enabled, however, the default state of the outputs of these devices is selectable. Devices are available with a maximum data rate of either 25Mbps or 200Mbps, and with outputs that are either default-high or default-low.

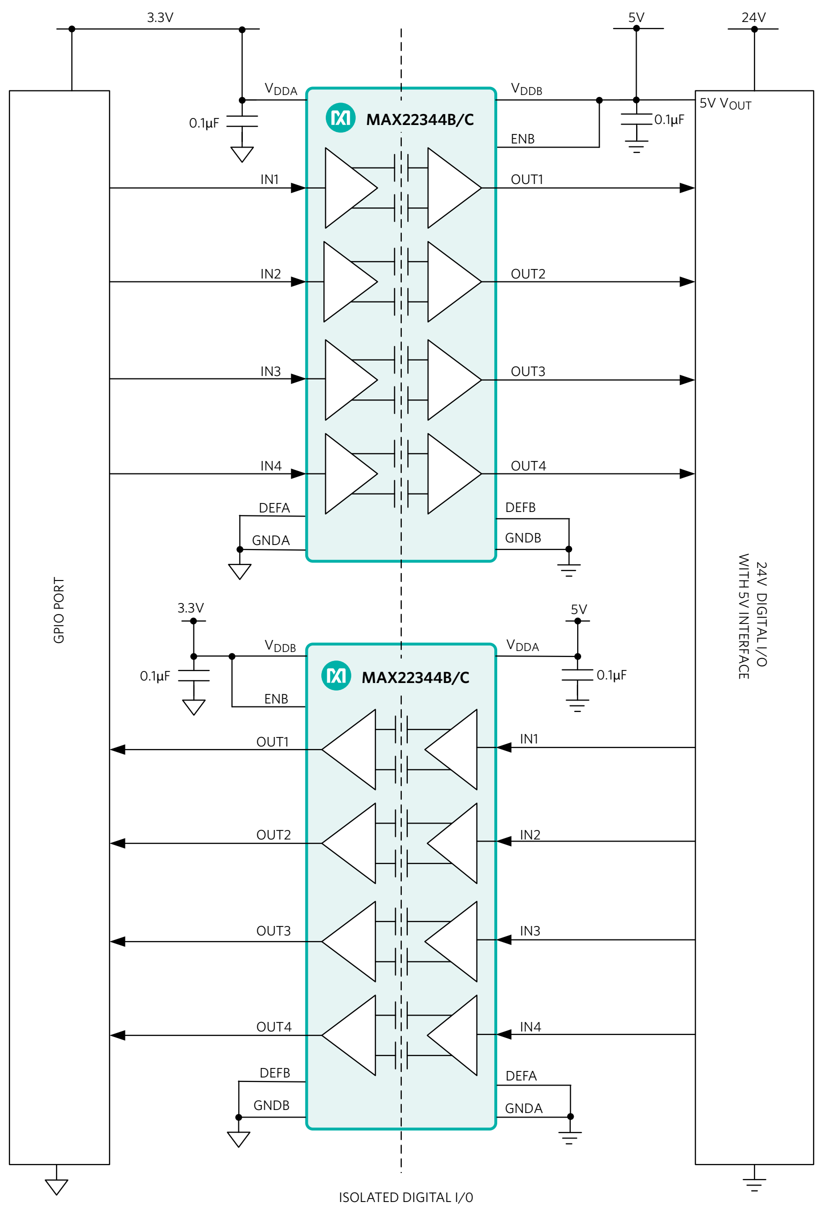


Figure 16. MAX2244x Typical Application Circuit

The key specifications for the isolators included in this section are summarized in **Table 5**.

Digital Isolator Summary

Table 5. Summary of DIO-Compatible Isolator

Products*	Channels	Isolation Rating (V_{RMS})	Data Rate (Mbps)	Package Creepage (mm)	Feature
MAX14930 MAX14931 MAX14932	4	2.75k, 3.75k	1, 25,150	N-SOIC-16 / 4mm W SOIC-16 / 8mm	Basic Isolation
MAX14934 MAX14935 MAX14936	4	5k	1, 25,150	W-SOIC-16 / 8mm	Basic Isolation
MAX14130 MAX14131	4	1k	150	QSOP / 3.8mm	Basic Isolation, Smaller QSOP
MAX12930 MAX12931	2	3k or 5k	25, 150	N-SOIC-8 / 4mm W-SOIC16 / 8mm	Basic Isolation
MAX12934 MAX12935	2	5k	25, 200	W-SOIC-16 / 8mm	Basic Isolation
MAX14430 MAX14431 MAX14432	4	3.75k	25, 200	N-SOIC-16 / 4mm QSOP/3.8mm	Basic Isolation, lowest power
MAX14434 MAX14435 MAX14436	4	5k	25, 200	W-SOIC-16 / 8mm	Basic Isolation, lowest power
MAX14483	6	3.75k	200	SSOP-20 / 5.5mm	SPI Basic Isolation
MAX22344 MAX22345 MAX22346	4	3.75k	25, 200	SSOP-20 / 5.5mm	Reinforced Isolation
MAX22444 MAX22445 MAX22446	4	5k	25, 200	W-SOIC-16 / 8mm	Reinforced Isolation
MAX22245 MAX22246	2	5k	25, 200	W-SOIC-8 / 8mm	Reinforced Isolation
MAX22563 MAX22564 MAX22565 MAX22566	6	3.75k	25, 200	SSOP-20 / 5.5mm	Reinforced Isolation

* All products have a 1.71V to 5.5V operating voltage.

N-SOIC = Narrow SOIC; W-SOIC = Wide SOIC.

Part 2: Analog IO

Analog Input

Unlike a digital input, which is used to monitor the binary status or discrete threshold levels of industrial sensors, an analog input (AI) is used to monitor the state of instruments making continuous measurements e.g., the volume or pressure of fluid in a vessel, motor speed, flow rates, and proximity measuring. Since these signals are often required to travel long distances in electrically noisy environments, an electrical current, instead of a voltage is often used. For legacy reasons, currents in the range of 4-20mA are used. High-precision external resistors can be used to convert current to a desired input voltage range. RTD and thermocouples used for temperature measurement generate different current and voltage levels. High-accuracy, low-error signal conversion is a critical performance parameter for AIs.

The 12-Channel Factory-Calibrated Configurable Analog Input

The **MAX22005** (**Figure 17**) is a twelve-channel industrial-grade analog input voltage-mode device that can also be configured to operate as an analog input current-mode device using a single external precision resistor per channel. It can also operate as a configurable analog-input using an external precision resistor and low-cost switch on each channel. Input channels can be used as twelve single-ended, six differential, four configurable or any combination thereof. This IC features an integrated 24-bit delta-sigma ADC that is shared between all channels. The ADC can be used with either an integrated 5ppm/°C precision reference or an external voltage reference. Standard industrial analog input voltage ranges are converted to the ADC input voltage range using high-voltage, zero-drift input amplifiers. All input ports are robustly protected up to ±36V reverse polarity and ±2kV surge pulses without the need for additional TVS diodes. Eight general-purpose GPIO ports are available for common use, or they can be used to control external switches for configurable inputs. Factory calibration ensures best-in-class system performance of less than 0.05% FSR total-unadjusted-error (TUE) over temperature. Configuration and information management is via a high-speed 30MHz SPI bus, which can also be used to acquire conversion results. An optional 8-bit CRC enhances the reliability of the SPI interface, helping to protect against all 8-bit bursts, all double-bit errors and most large clusters of errors. The MAX22005 operates from 2.7V to 3.6V analog and digital supplies, and up to ±24V high-voltage supplies.

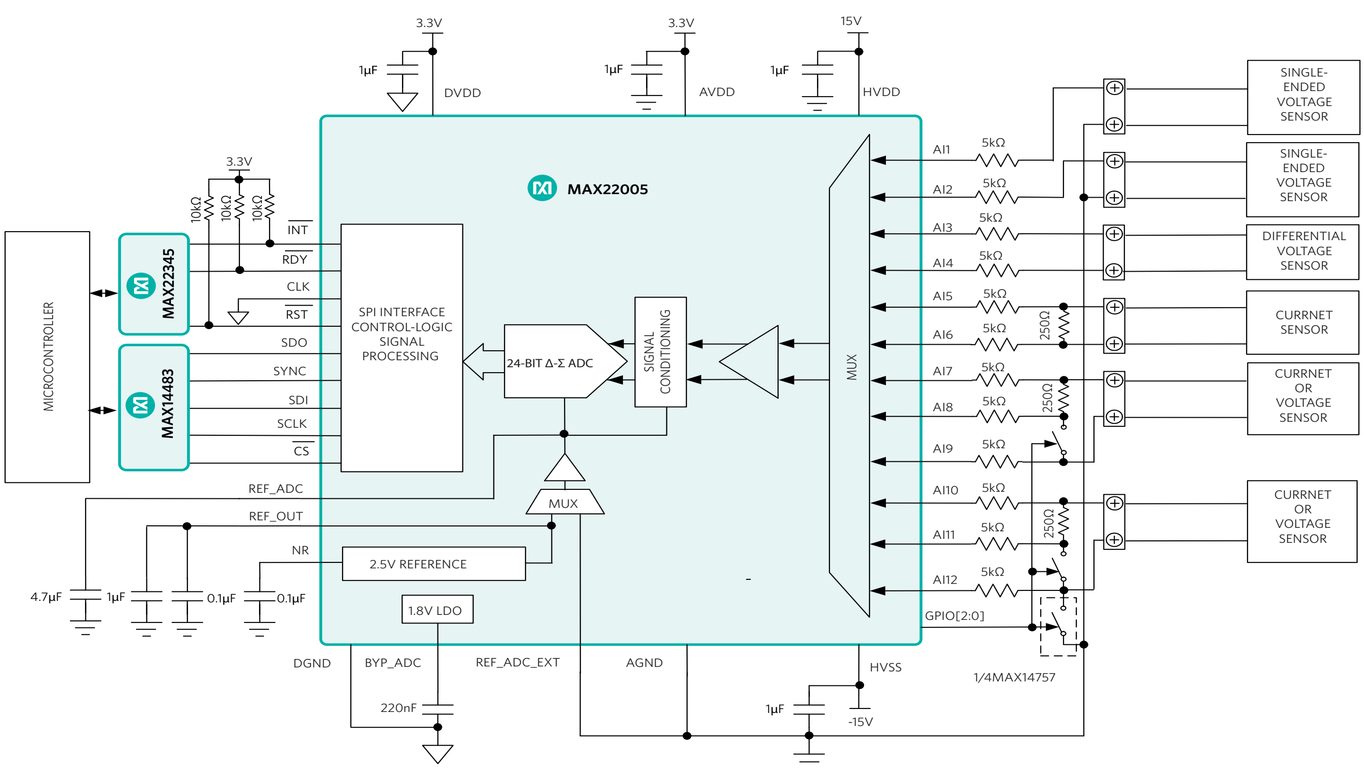


Figure 17. MAX22005 12-Channel Configurable Industrial Analog Input

Analog Output

The purpose of an analog output is to deliver a continuous voltage or current (4-20mA) signal for precision control of factory-floor actuators (e.g., in valves to control the flow of fluids), variable speed motors, and temperature controllers. Key specifications for these parts include a high-precision DAC, range of resolutions, and robust performance in harsh environments.

Four-Channel 12-Bit Configurable Analog Output

The **MAX22007** (**Figure 18**) is a factory-calibrated, software-configurable four-channel analog output capable of delivering a voltage or current output on each channel. All outputs are protected to ±42V_{P-P}. Each output channel features a fast 12-bit DAC which uses a shared internal voltage reference. The device offers low-offset, high-voltage amplifiers to condition the signal from low-voltage DAC outputs to high-voltage or current outputs. If one output is mis-wired, all other outputs remain unaffected and function normally. For each channel, an internal comparator can be used to determine the load impedance allowing the microcontroller to intelligently select for voltage or current output mode. All outputs are protected by integrated current protection for functional and thermal robustness. This IC also includes a thermal shutdown circuit that protects the device when the junction temperature exceeds +165°C. Communication with a microcontroller takes place using a SPI interface at clock rates up to 30MHz, with an optional eight-bit CRC for improved data integrity. Eight GPIOs are provided that can be used to interface with or control other resources in the application circuit. The MAX22007 operates from a 2.7V to 5.5V V_{DD} low-voltage supply and an 8V to 24V HVDD positive high-voltage supply. The negative voltage supply HVSS can be set between -2V and 0V.

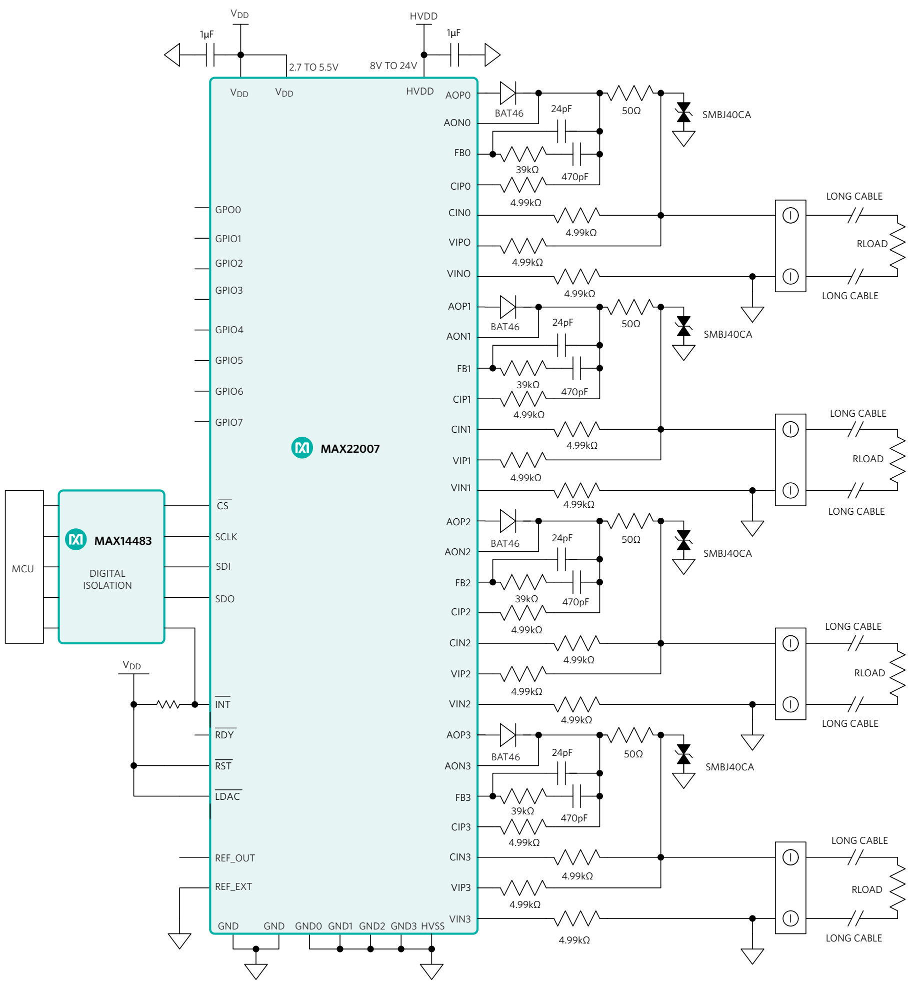


Figure 18. Two-Wire Application Circuit Using MAX22007

CONFIGURABLE ANALOG IO

Industrial Configurable Analog I/O

The **MAX22000** (**Figure 19**) is an industrial-grade configurable analog input/output device that can be configured in software as any desired combination of voltage/current, input/output. Additional inputs are available to measure other analog signals (RTD and thermocouple). The device offers a fast-settling 18-bit DAC and a 24-bit delta-sigma ADC. The ADC and DAC can individually select between an internal or an external reference voltage. The ADC is supported by a low-noise programmable gain amplifier (PGA), with high-voltage and low-voltage input ranges to support RTD and thermocouple measurements. Additional auxiliary inputs are provided to measure cold junction temperatures on-board. The MAX22000 communicates through a high-speed 20MHz SPI bus for all configuration and management information and for conversion results. An optional 8-bit CRC enhances the reliability of the SPI interface, protecting against all 8-bit bursts as well as all double-bit errors. This IC operates from 2.7V to 3.6V analog and digital supplies and up to ±24V high-voltage supplies.

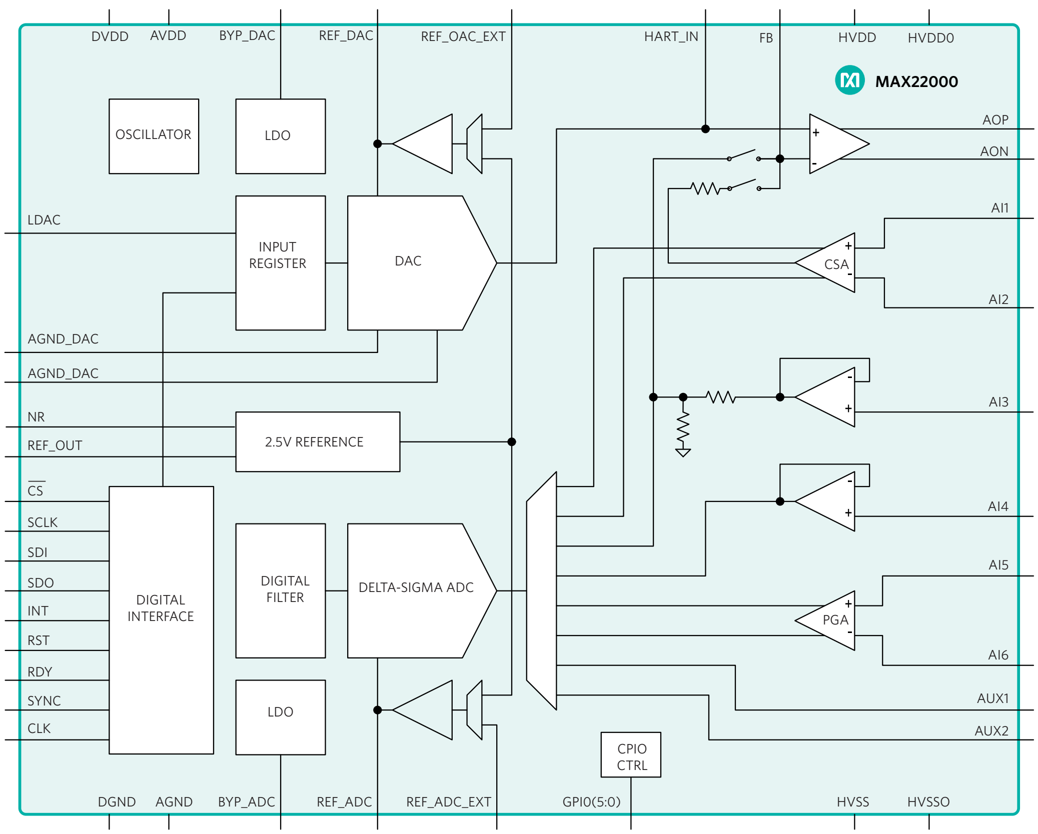


Figure 19. MAX22000 Configurable Analog IO

A summary of the main features of Maxim's portfolio of analog IO ICs is presented in **Table 6**.

Analog IO Summary

Table 6. Summary of Analog IO ICs

Part Number	Direction	No. of Channels	Resolution	Max I/O Voltage Range (V)	Max I/O Current Range (mA)
MAX22005	Input	12	24-bit	±12.5	±25
MAX22007	Output	4	12-bit	±10.5	±20
MAX22017*	Output	2	16-bit	±12.5	±25
MAX22000	Input and Output	6 I/P +1 O/P	24-bit / 18-bit	±12.5	±25

Analog IO Companion ICs

Single-Channel Isolated 10-Bit ADC with Integrated DC-DC

The **MAX14001** and **MAX14002** (**Figure 20**) are isolated, single-channel MAXSafe™ analog-to-digital converters (ADCs) with programmable voltage comparators and inrush current control optimized for configurable binary input applications. Integrated isolation of 3.75kV$_{RMS}$ is provided between the binary input side (field-side) and the comparator output/SPI-side (logic-side). An integrated, isolated, DC-DC converter powers all field-side circuitry from a 3.0V to 5.5V logic-side supply, enabling field-side diagnostics, even in the absence of an input signal. The 20-pin SSOP package provides 5.5mm of creepage and clearance with a Group II CTI rating. These devices continually digitize the input voltage on the field side of the isolation barrier and transmit the data across the isolation barrier to the logic side of the device where the magnitude of the input voltage is compared to programmable thresholds. The binary comparator output pin is high when the input voltage is above the upper threshold and low when it is below the lower threshold. Response time of the comparator to an input change is less than 150µs with filtering disabled. With filtering enabled, the comparator uses the moving average of the last 2, 4, or 8 ADC readings. Both filtered and unfiltered ADC readings are available through the 5MHz SPI port, which is also used to set comparator thresholds and other device configurations. The MAX14001/ MAX14002 control the current of a binary input through an external, high-voltage FET. This current cleans relay contacts and attenuates input noise. An inrush comparator monitoring the ADC readings triggers the inrush current, or wetting pulse. The inrush trigger threshold, current magnitude, and current duration are all programmable in the MAX14001 but are fixed in the MAX14002. When the high-voltage FET is not providing inrush current, it switches to bias mode. Bias mode places a small current load on the binary input to attenuate capacitively coupled noise. The level of bias current is programmable between 50µA and 3.75mA in both the MAX14001 and MAX14002. This allows optimization of the tradeoff between noise attenuation and power dissipation.

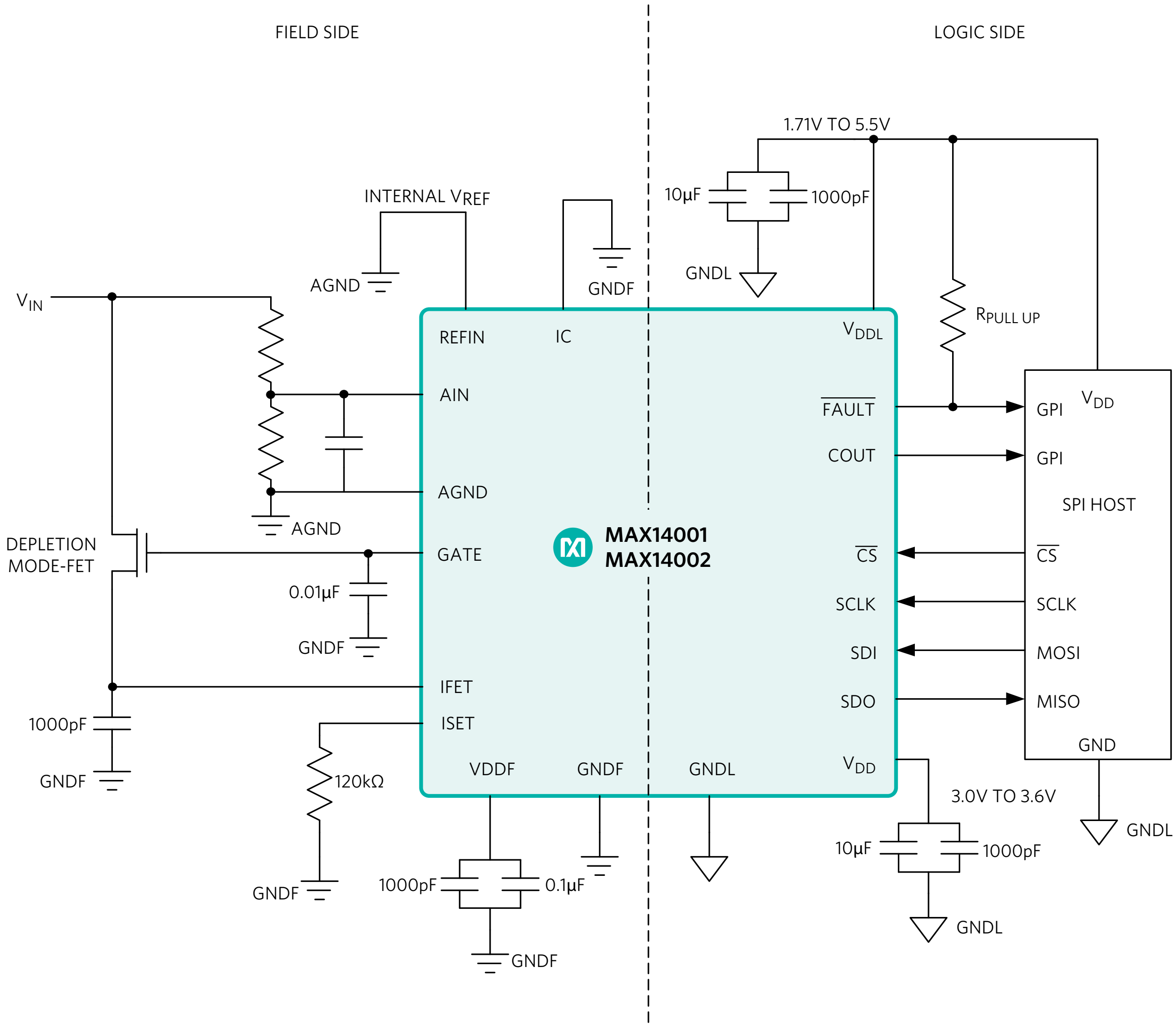


Figure 20. MAX14001/MAX14002 Typical Application Circuit

Field-Side Self-Powered 4-Channel 12-Bit Isolated ADC

The **MAX22530**/**MAX22531**/**MAX22532** (**Figure 21**) are galvanically isolated, 4-channel, multiplexed, 12-bit ADCs in the MAXSafe family product line. An integrated, isolated, DC-DC converter powers all field-side circuitry from a 3.0V to 5.5V logic-side supply which allows field-side diagnostics even when no input signal is present. These ADCs continually digitize the input voltage on the field side of an isolation barrier and transmit the data across the isolation barrier to the logic side of the devices where the magnitude of the input voltage is compared to programmable thresholds. The 12-bit ADC core has a typical per-channel sample rate of 20ksps. ADC data is available through the SPI interface either directly or filtered. Filtering averages the most recent four readings. Each input has a comparator with programmable high and low thresholds, and an interrupt is asserted when any input crosses its programmed level based on the mode setting. The MAX22530 in a 16-pin wide SOIC package provides 8mm of creepage and clearance, and $5kV_{RMS}$ isolation. The MAX22531 in a 20-pin SSOP package and the MAX22532 in a 28-pin SSOP package, both provide 5.5mm of creepage and clearance, and $3.5kV_{RMS}$ isolation. All package material has a minimum comparative tracking index (CTI) of 400, which corresponds to a group II rating in creepage tables.

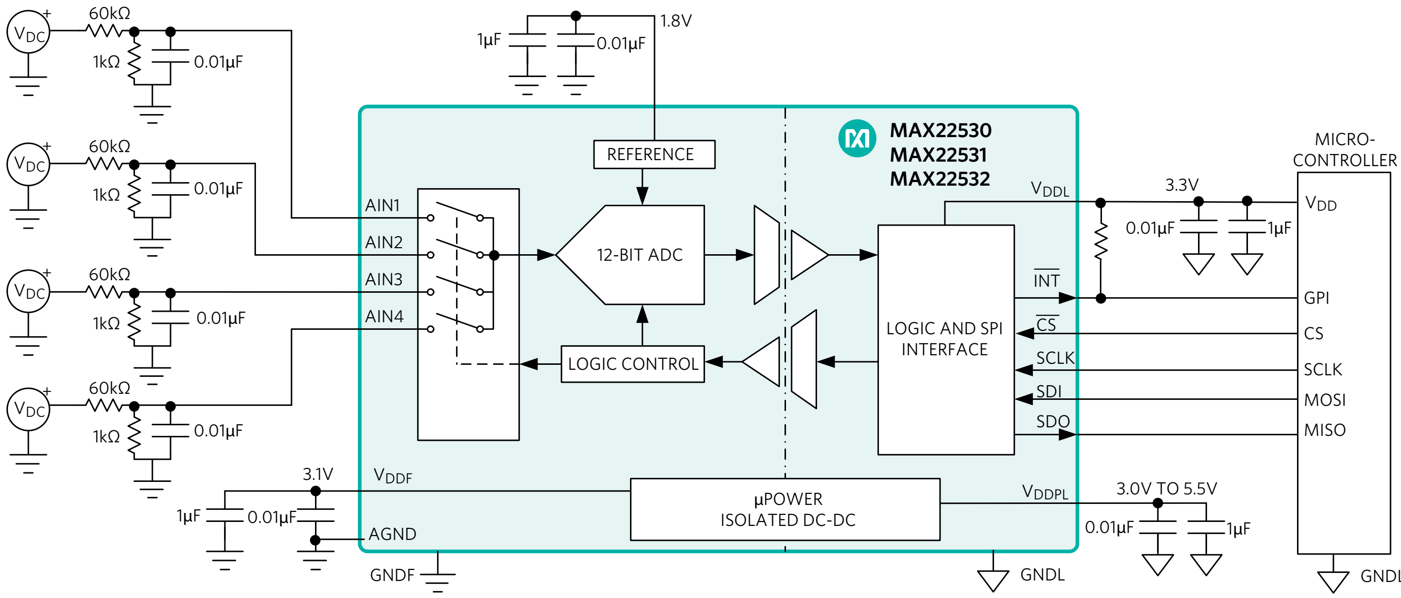


Figure 21. MAX22530/MAX22531/MAX22532 Isolated 12-Bit ADC

Isolated ADCs Summary

The key specifications for the isolated ADC ICs included in this section are summarized in **Table 7**.

Table 7. Summary of Isolated ADC ICs

Part Number	Number of Channels	Number of Bits	Sampling Rate (ksps)	Package	V_{ISO} (kV_{RMS})	Features
MAX14001	1	10	10	SSOP-20	3.75	Programmable thresholds and wetting current
MAX14002	1	10	10	SSOP-20	3.75	Fixed thresholds and wetting current
MAX22530	4	12	20	WSOIC-16	5kV	No comparator outputs
MAX22531	4	12	20	SSOP-20	3.5	2 comparator outputs
MAX22532	4	12	20	SSOP-28	3.5	4 comparator outputs

Part 3: Industrial IO Design Resources

Designing Digital Output Modules for High Current Inductive Loads

Inductive Loads and Diode Protection

Typical inductive loads present on the factory floor include motors, solenoids, and electromechanical relays. Inductive kickback (surge) occurs when an electrically generated field collapses. A voltage spike occurs over the load in the opposite direction (polarity) to maintain the current flow. This fast and large voltage potential is also imposed on the FET or transistor, where it can be high enough to cause electrons to jump across the junction, possibly causing irreparable damage, or at the very least, shortening the life of the device. In a practical circuit, the most common solution to discharge the inductive load (**Figure 22**), uses a free-wheel diode. In this circuit, while the switch is closed, the diode is reverse-biased and does not conduct any current. When the switch opens, the negative voltage across the inductor forward biases the diode, allowing the stored energy to decay by conducting the current through the diode until steady state is reached and the current is zero.

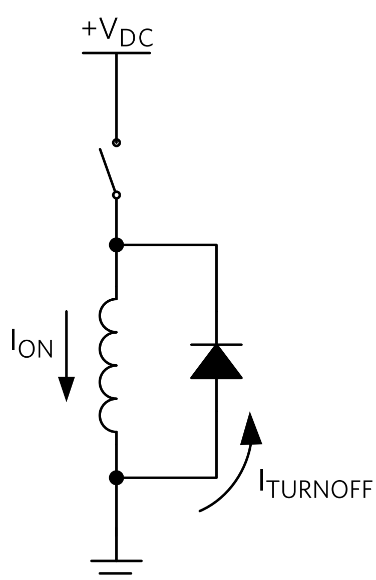


Figure 22. Freewheel Diode

The diode must handle the initial current at turn-off, which equals the steady-state current flowing through the inductor when the switch is closed. In addition, the voltage rating for the diode needs to handle the swing between positive and negative-voltage levels. A rule-of-thumb is to select a diode rated for at least the amount of current the inductor coil draws and at least twice the voltage rating of the operating voltage of the load. For industrial applications that have many output channels per IO card, this diode is quite often physically large and adds significant cost to the BOM. The other major disadvantage of the simple freewheel diode approach is that it lengthens the decay of current through the inductor and the slow decay of current creates problems such as "sticking" between relay contacts. For applications where the current must decay more quickly, an alternative solution is to use a Zener diode, as shown in **Figure 23**, which gives a faster current ramp rather than an exponential decay. When the switch opens, the current is shunted through the general-purpose diode and Zener diode path. This maintains a voltage equal to the Zener voltage (plus the forward diode drop) until the inductor energy is dissipated.

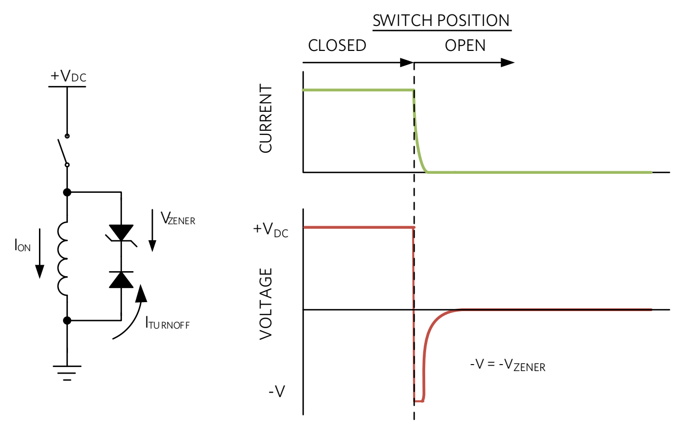


Figure 23. Zener Diode for Faster Current Decay

Active Clamping Using MOSFETs

For industrial applications, the 'switch' is usually a MOSFET. When a MOSFET turns off while switching an inductive load (if no protection is available), the voltage across the drain and the source (V_{DS}) increases until the MOSFET breaks down. Modern high-side switches frequently use a technique called active clamping (**Figure 24**) that limits V_{DS} when switching inductive loads to protect the MOSFET. When the switch is closed, the MOSFET operates fully on in saturation mode (R_{DS} is low), but when the switch is opened, the MOSFET is driven into its linear mode where R_{DS} is higher resistance. The load demagnetizes quickly during the active clamp mode because a larger voltage (V_{DD} - V_{CLAMP}) dissipates the stored energy. The larger the voltage difference, the faster the demagnetization. Therefore, switch IC vendors often refer to this feature as 'fast-demag.'

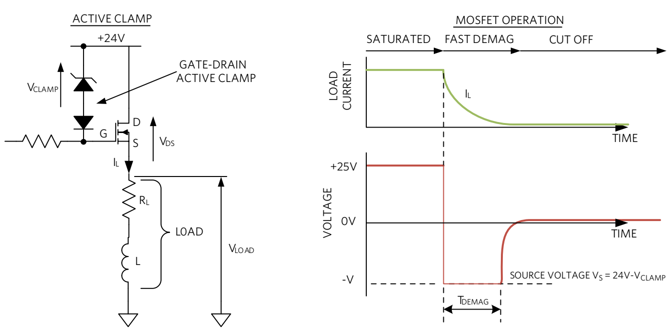


Figure 24. High-Side Switch (MOSFET) with Active Clamp

During demagnetization, the MOSFET dissipates more power than the load since the voltage across the MOSFET is higher than the load voltage. This means that for each switch there is a maximum inductive load and load current that can be supported; otherwise, the MOSFET will have thermal issues during active clamp mode. It is the system designer's responsibility to ensure that the switch (MOSFET) can handle the higher power that is dissipated during the turn-off mode. Otherwise, the increase in junction temperature can cause stress and possible damage to the switch device. This condition is worse for multi-channel switches that are popular in industrial control applications.

Safe Demagnetization

Although high-side switches typically have overcurrent and overtemperature detection features, during active clamp mode (fast demag), the current is controlled by the energy in the load, so no protection (current or temperature) is active during this mode. To solve the issue of excessive energy dissipation during fast demag and the thermal issues of the MOSFET, the MAX14912/MAX14913 octal high-speed switches employ a new architecture called safe demagnetization (SafeDemag). SafeDemag (**Figure 25**) works in conjunction with the fast demag circuitry and allows the MAX14912/MAX14913 to safely turn off loads with unlimited inductance. Under normal turn-off, the high-side MOSFET works in linear mode to dissipate the inductor energy using the fast demag feature. If the energy in the inductor, and hence the demagnetization current, is too high, the high-side MOSFET begins to overheat. At this point, an on-chip temperature sensor alerts the control logic to turn off the high-side MOSFET and turns on the low-side MOSFET, which provides a low-voltage (and hence low power dissipation) alternative path for the demagnetization current. This allows the high-side MOSFET to cool and return to safe operating limits. For a full list of products with various demag features, see **Table 8**.

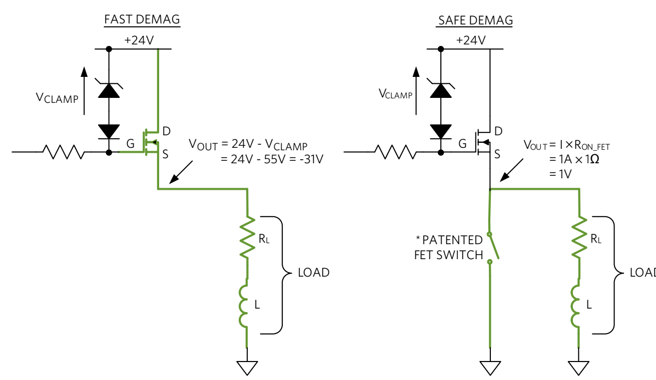


Figure 25. Current Paths for Safe Demagnetization

Table 8. Summary of DO Products by Demag Feature

Part Number	Demag Feature
MAX14906	Safe
MAX14912	Safe
MAX14913	Safe
MAX14914/MAX14914A/MAX14914B	Safe
MAX14915	Fast
MAX14916	Fast
MAX14917	Fast
MAX14900E	Slow

System Design Recommendations for Transient Immunity

Digital Input ICs are required to operate reliably in harsh industrial environments. Maxim's proprietary process technology combines internal ESD structures with high absolute maximum ratings to make input channels and field supply pins very robust, but external components are required to absorb excessive energy from ESD and surge transients. Transient immunity requirements as specified in IEC 61131-2, include:

- Electrostatic Discharge (IEC 61000-4-2)
- Electrical Fast Transient (IEC 61000-4-4)
- Surge Immunity (IEC 61000-4-5)

The external components in the circuit shown (**Figure 26**) enables the **MAX22199** DI device to meet and exceed the transient immunity requirements as specified in the IEC 61131-x standards. A list of recommended components is shown in Table 9, to make the MAX22199 robust enough to meet the ESD, EFT, and surge specifications. For all tests, the part is soldered onto a properly designed application board e.g., the **MAX22199EVKIT#** (**Figure 29**) with the necessary external components.

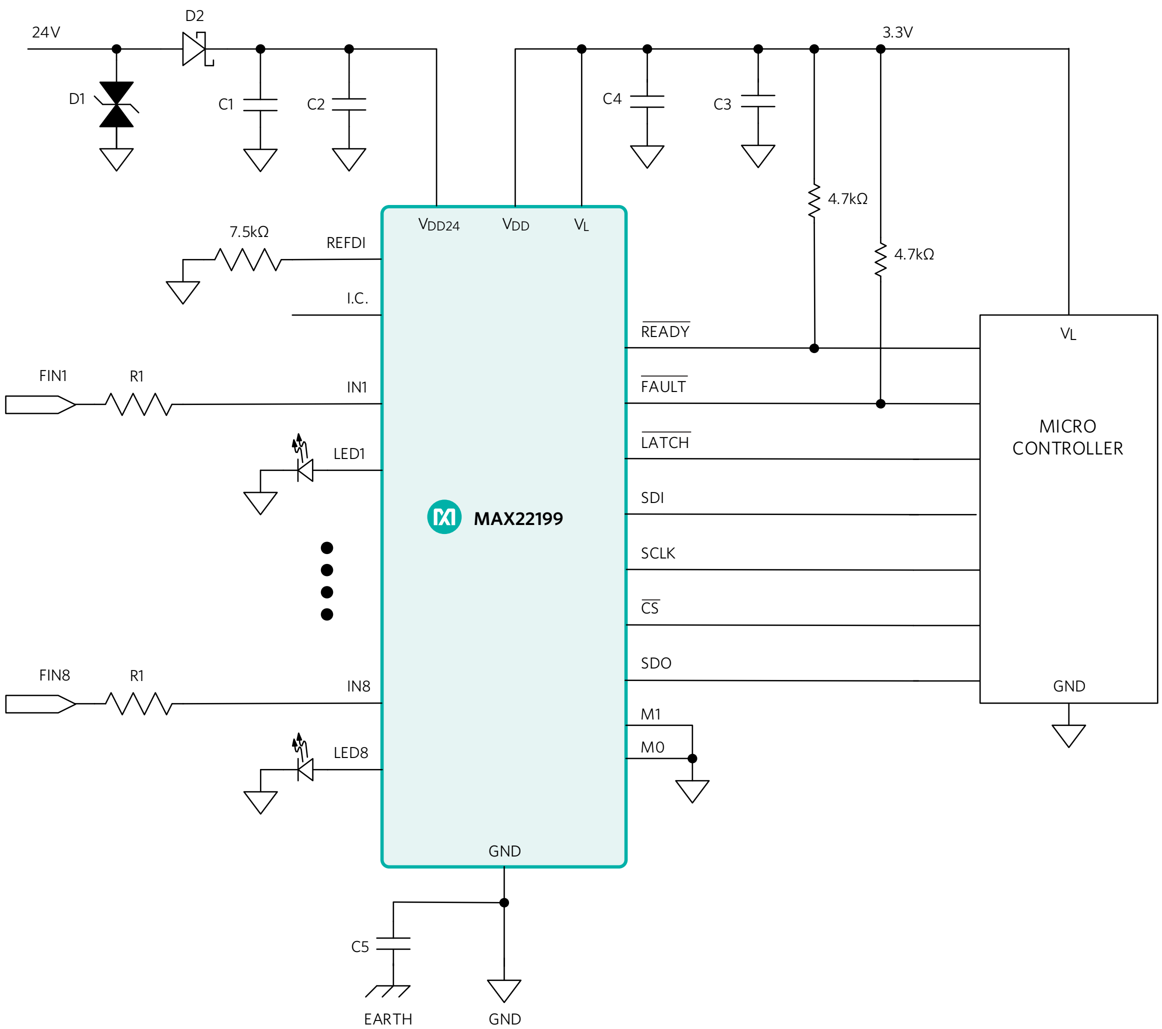


Figure 26. MAX22199 DI IC with External Protection Components

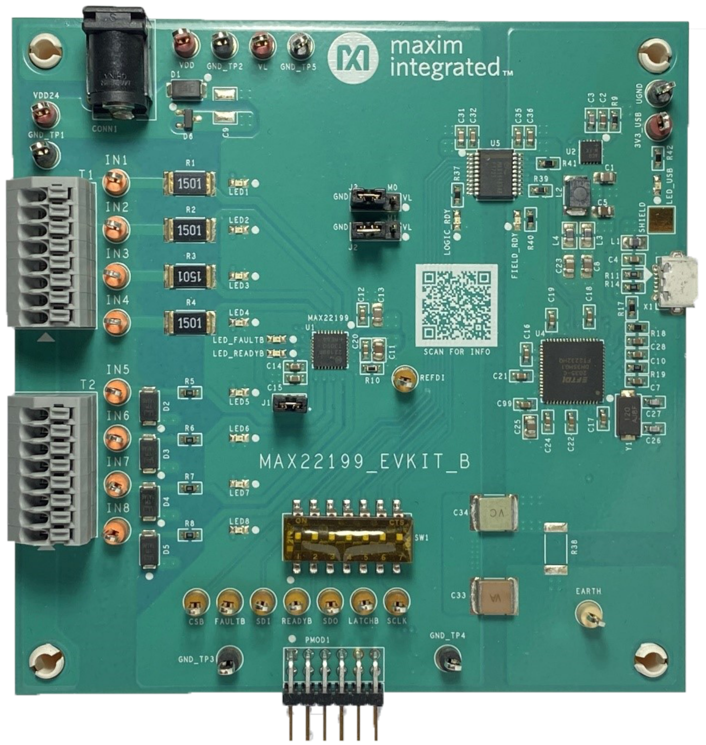


Figure 27. MAX22199EVKIT# Evaluation Board

Table 9. Recommended Components for Transient Immunity Protection

Component	Description	Required/Recommended/Optional
C1	1µF, 100V low ESR ceramic capacitor	Required
C2	0.1µF, 100V low ESR ceramic capacitor	Required
C3	1µF, 10V low ESR ceramic capacitor	Required
C4	0.1µF, 10V low ESR ceramic capacitor	Required
C5	3300pF safety rated Y capacitor (2220)	Recommended
D1	Bidirectional TVS diode, SMAJ33CA (42Ω) or SM30T39CAY (2Ω)	Recommended
D2	Schottky diode for reverse current protection	Recommended
R1	1.5kΩ or 1kΩ, 1W pulse withstanding resistor (CMB0207, RPC2512, CRCW2512-IF or similar)	Required
All other resistors	0603, 0.1W resistors	Required
All LEDs	LED for visual input status indication	Recommended

An alternative method of implementing surge protection is to use a SMAJ33CA TVS with a regular resistor. The benefit of this solution is a smaller footprint and it allows for a higher surge rating on the input channel (depending on the choice of TVS). For user comparison, both methods are implemented on the MAX22199EVKIT (channels 1-4 use the surge resistor method while channel 5-8 use TVS).

ESD Protection of Field Inputs

An ESD-rated input resistor limits the energy at the input pins of the MAX22199 and protects the internal ESD structures from large transient voltages. Input channels can withstand up to ±8kV ESD contact discharge and ±15kV ESD airgap discharge with an input series resistor of at least 1kΩ. The input resistor value shifts the field voltage switching threshold (scaling by the product of input current) thereby determining the input characteristics of the application. The resistor package should be large enough to prevent arcing across the two resistor pads.

EFT Protection of Field Inputs

A capacitive coupling clamp is used to couple the fast transients (burst) from the EFT generator to the field inputs of the MAX22199 without any galvanic connection. The input channels can withstand up to ±4kV, 5kHz, or 100kHz fast transients with performance criterion A (normal operation within specification limits).

Surge Protection of Field Inputs

The MAX22199 EV kit uses two methods to protect the IC input pins against surges specified in IEC 61000-4-5:

- The first (channels 1-4) uses a series pulse withstanding resistor with no filtering capacitors for filtering.
- The second (channels 5-8) uses a bidirectional TVS to GND at the field input with a low-power series resistor.

Surge Protection of 24V Supply

To protect the VDD24 pin against 500V/42Ω, 1.2/50µs surges, a SMAJ33CA TVS can be applied to the VDD24 pin, along with a series Schottky diode for reverse current protection.

Y Capacitor

In critical applications, a safety-rated Y capacitor across the isolation barrier is recommended (**Figure 28**). For example, in EFT testing of the MAX22192 (with integrated isolation barrier), the Y capacitor reduces the dV/dt seen by the isolator, thereby improving the EFT performance and protecting the isolator barrier. The Y capacitor must be connected between field GND and Earth (PE) so that the large EFT current is redirected to Earth without disturbing logic-side components. In addition, a resistive discharge path (> 100MΩ) may also be implemented across the barrier to discharge the Y cap. The recommended board placement for the Y capacitor is shown in **Figure 29**.

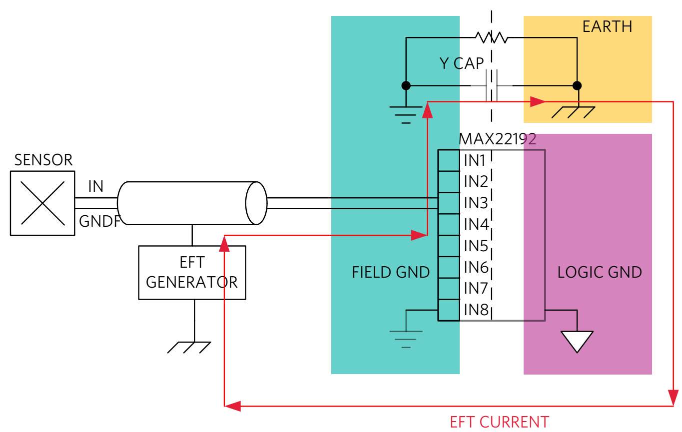


Figure 28. Y Capacitor for Extra Protection

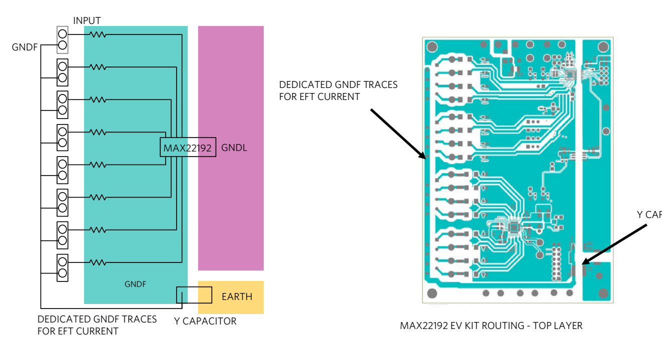


Figure 29. Redirect Current to Earth Through the Y Capacitor

Testing Setup

A typical bench test setup for IEC immunity testing is shown in **Figure 30**. For surge testing, a 40Ω + 0.5µF coupling/decoupling network is used with the surge generator. For electrical fast transient (EFT) testing, a capacitive clamp is used with the EFT generator.

Evaluation of Test Results

Test results are classified at different levels, with the required performance criteria determined by the nature of end equipment and its application. Typical results, as classified in IEC 61000-4-x, are shown in **Table 10**.

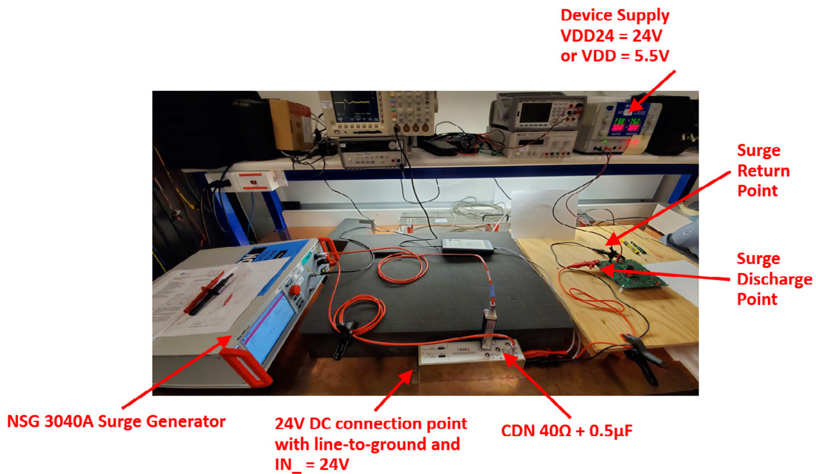


Figure 30. Transient Immunity Bench Test Setup

Table 10. IEC 61000-4-x Performance Criteria

Performance Criterion	Description
A	Normal operation within specified limits
B	Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which EUT recovers its normal performance, without operator intervention
C	Temporary loss of function or degradation of performance, the correction of which requires operator intervention
D	Loss of function or degradation of performance, which is not recoverable

A summary of test results for the MAX22199 is shown in **Table 11**. The input channels can withstand up to ±4kV EFT with performance criterion A.

Table 11. MAX22199 Transient Immunity Testing and Results

Test		Result
IEC 61000-4-2 Electrostatic Discharge (ESD)	Contact ESD	±8kV
	Air-Gap ESD	±15kV
IEC 61000-4-4 Electrical Fast Transient/ Burst (EFT)	Input Line	±4kV
IEC 61000-4-5 Surge Immunity (1.2/50µs, 42Ω	Line-to-Ground	±2kV
	Line-to-Line	±2kV
	Power Supply	±500V

Industrial IO Evaluation Boards and Peripheral Modules

All our industrial IO products come with GUI-controlled evaluation kits, which can be used to exercise the main features of an IC and are mostly suitable for performance testing over their specified temperature range or for transient immunity testing. For engineers who wish to evaluate our ICs quickly and conveniently in product prototypes using their own MCU or FPGA board and software, we provide peripheral modules (Pmod™). These are small IO interface boards that communicate with system boards using 12-pin connectors for easy, low-cost testing. Our Pmod boards can be connected to the USB port of a PC using separate adapter boards (USB2PMB1, USB2PMB2, and USB2GPIO) with communication controlled using Maxim's Munich GUI . Alternatively, a 12-pin Pmod-compatible microcontroller or FPGA can be used. Yet another option is to wire-wrap a temporary connection from the system to the pins on the Pmod connector. For the latter two options, users must write their own control software.

Pmod Adapter Boards

Low-cost adapter boards (available separately) allow the Pmod boards (**Table 12**) to be connected to the USB port of a PC, handling the necessary translation to I²C or SPI commands as required.

Table 12. Pmod Adapter Boards

Board Number	Description	Comments
USB2PMB1#	USB Adapter - SPI pinout	Recommend using USB2PMB2#
USB2PMB2#	USB Adapter - SPI/I²C pinout	
USB2GPIO#	USB Adapter - SPI/I²C pinout (12-pin connector) and 16 GPIOs with SPI or I²C pinout (20-pin connector)	Can be used without extra GPIOs
USB2GPIOISO#	Isolator Board for Optional Use with USB2GPIO	Features MAX14483 isolator

USB2PMB2

The **USB2PMB2** adapter (**Figure 31**) interfaces a USB port to either an SPI or I²C interface, with 4 additional GPIOs.

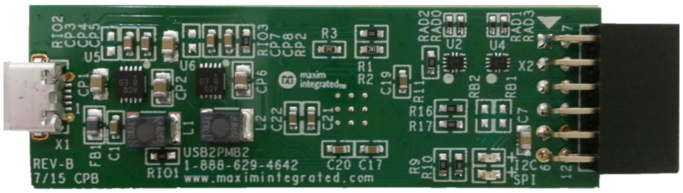


Figure 31. USB2PMB2 Adapter Board

USB2GPIO

The **USB2GPIO** adapter (**Figure 32**), which was designed to supersede the USB2PMB2, can be used to interface a USB port to a GPIO, SPI or I²C interface as required.

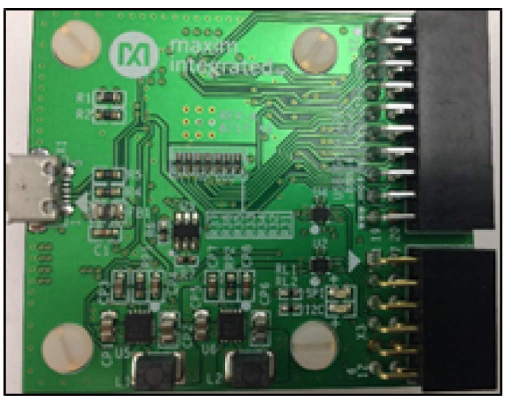


Figure 32. USB2GPIO Adapter Board

USB2GPIOISO

For prototypes that require an isolated interface, the **USB2GPIOISO** adapter (**Figure 33**) provides galvanic isolation using the **MAX14483** between the "master" USB2GPIO adapter board and a "slave" EV kit or Pmod board.

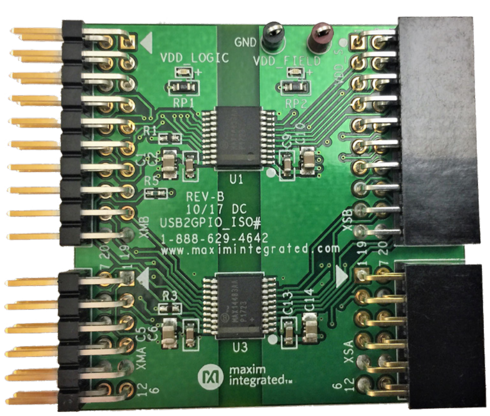


Figure 33. USB2GPIOISO Adapter Board

MicroPython Board

The **TMCM-0960-MotionPy** board (**Figure 34**) is an open-source single board computer running MicroPython. It comes with several communication interface options like CAN, RS-485, UART, and separate GPIO headers. With a wide selectable supply voltage range of 6V to 50V and industrial fieldbus interfaces, it is highly flexible for use in small automation applications. It can be plugged directly into an application for logging data onto an SD card, or used to update subsystems without the need for additional tools. The module provides a total of 13 functions in Python programming language for ease of use.

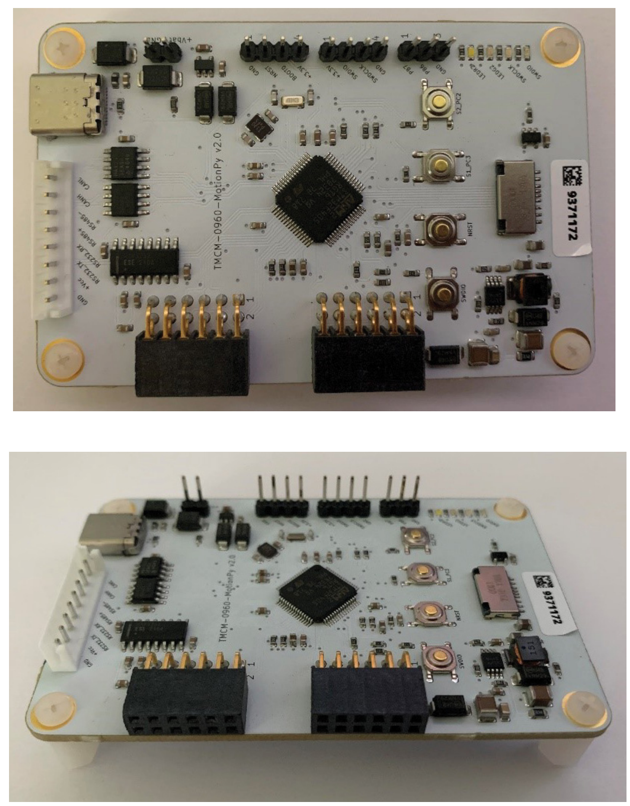


Figure 34. MicroPython Board

Reference Designs

To emulate real-world application of our industrial IO ICs, we have created a diverse set of reference designs. They have not been certified for use in the field but can be quickly leveraged to provide the basis for practical designs, to be later certified by OEMs.

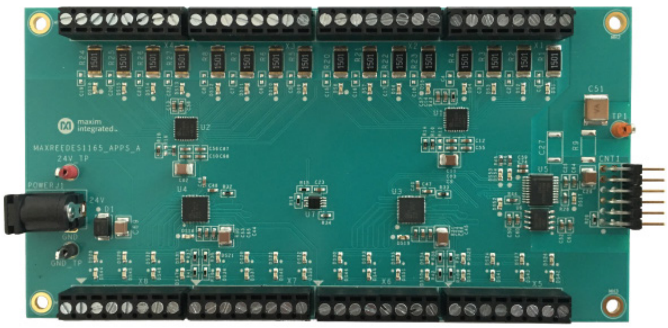


Figure 35. MAXREFDES1165 32-Channel IO Module

MAXREFDES1165 32-Channel Digital IO

The **MAXREFDES1165** (**Figure 35** and **Figure 36**) is a complete, 32-channel industrial digital I/O module comprising 16 digital inputs using two octal-channel digital input devices (MAX22190), and 16 digital output channels with two octal-channel digital output devices (MAX14915). It is built and tested in an industrial form factor to meet the IEC 61000-4-2/4/5 transient immunity standards.

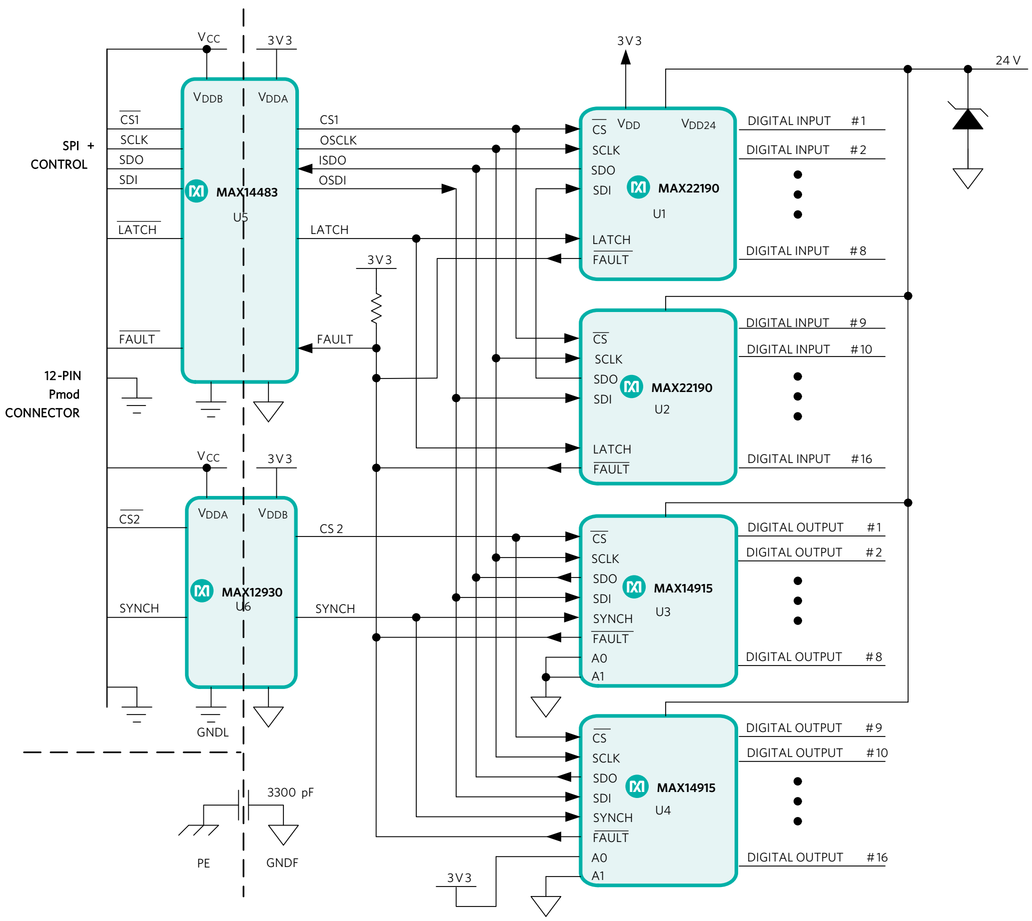


Figure 36. MAXREFDES1165 32-Channel IO Module System Block Diagram

MAXREFDES1165 32-Channel Digital IO

The **MAXREFDES176#** (**Figure 37**) is a complete, IO-Link 16-channel digital input hub reference design that includes the **MAX22515** IO-Link transceiver with integrated protection. It demonstrates an isolated digital input hub using the **MAX22192** isolated octal digital input device, daisy-chained with the **MAX22190** octal digital input device to provide a total of 16 digital input channels (**Figure 38**). Type 1 and Type 3 sensors are supported by default while Type 2 sensors can also be supported by modifying the resistor value that controls the value of the current sink within the devices. Built in an industrial form factor, the MAXREFDES176# uses an industry-standard M12 connector, allowing a 4-wire cable to be used. The digital input channels use industry-standard PCB terminal blocks.

Figure 37. IO-Link Transceiver Solution Comparison

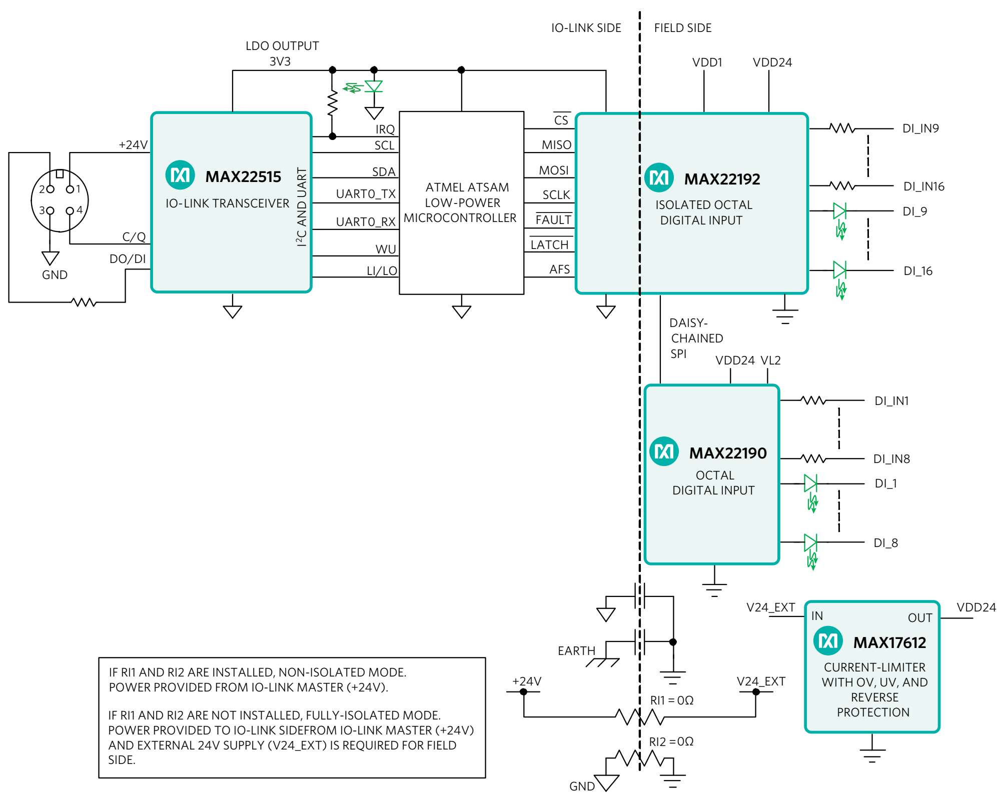


Figure 38. MAXREFDES176# System Block Diagram

MAXREFDES177# Universal Analog IO

The **MAXREFDES177#** (**Figure 39**) is a complete, IO-Link universal analog IO reference design that includes a **MAX22515** IO-Link transceiver with integrated protection. It demonstrates a fully software-configurable analog IO module using the MAX22000 industrial configurable analog IO device.

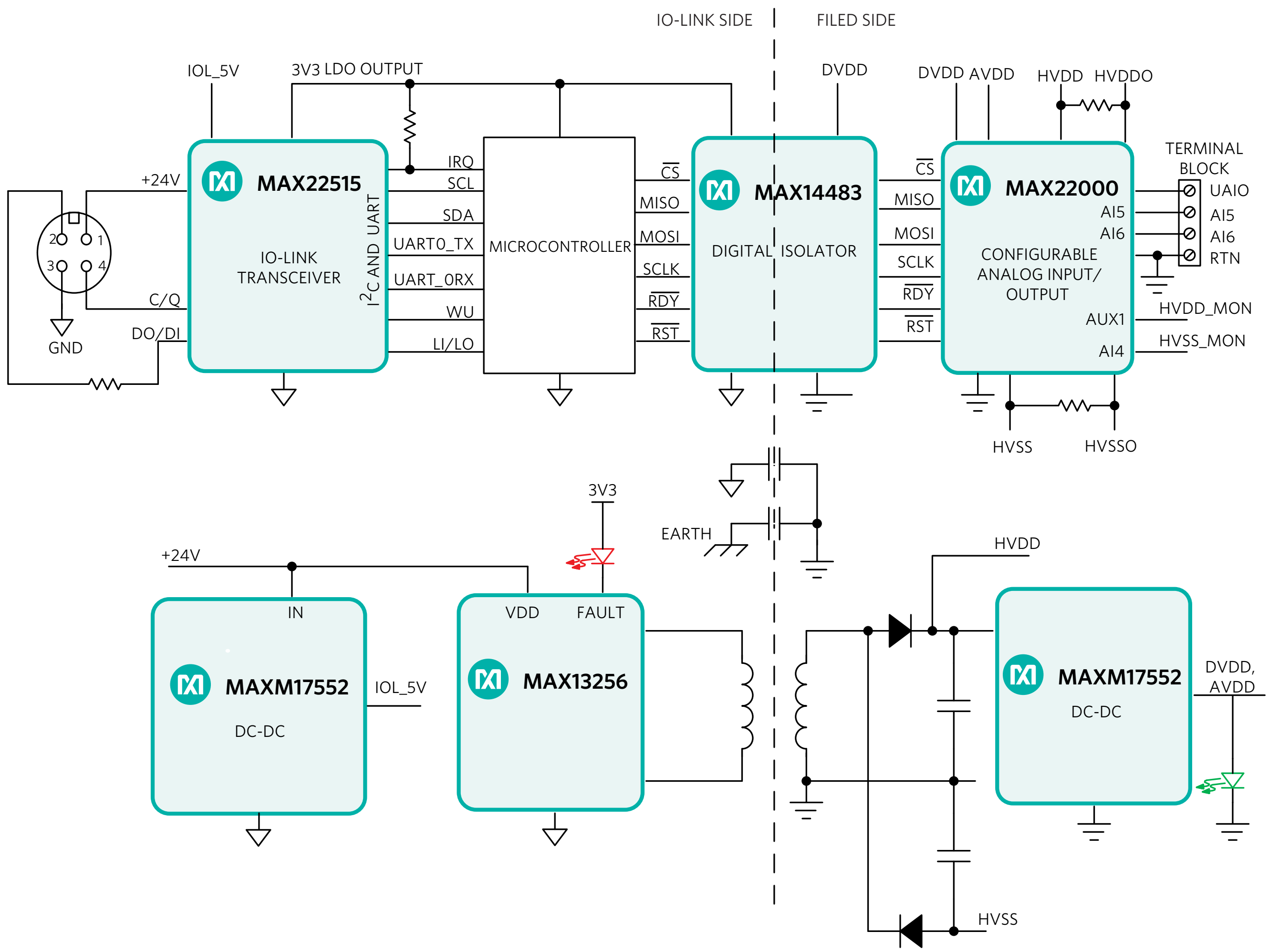


Figure 39. MAXREFDES177# Universal Analog IO

MAXREFDES183# High-Precision Calibrator

The **MAXREFDES183#** (**Figure 40**) is a complete, portable, battery-powered precision voltage/current calibrator reference design. It supports a fully software-configurable universal IO (analog input or output, voltage or current on a common pin) using the MAX22000 industrial-configurable analog IO device (**Figure 41**). Industry-standard banana plugs are used and include support for Kelvin sensing, remote temperature measurement using an RTD or a thermocouple, and temperature simulation. The MAXREFDES183# includes built-in temperature compensation and heating capabilities for precision measurements.

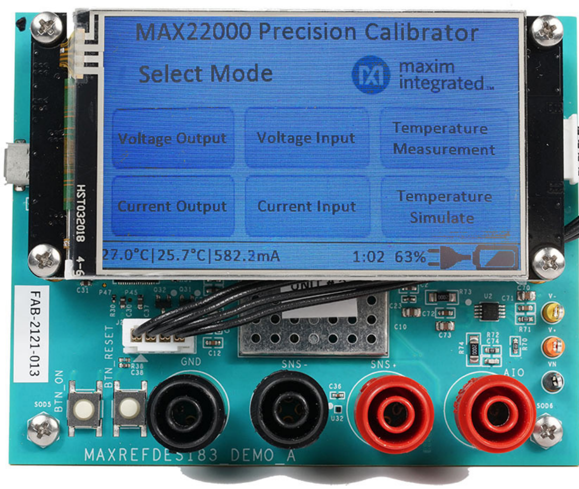


Figure 40. MAXREFDES183# Calibrator Reference Design

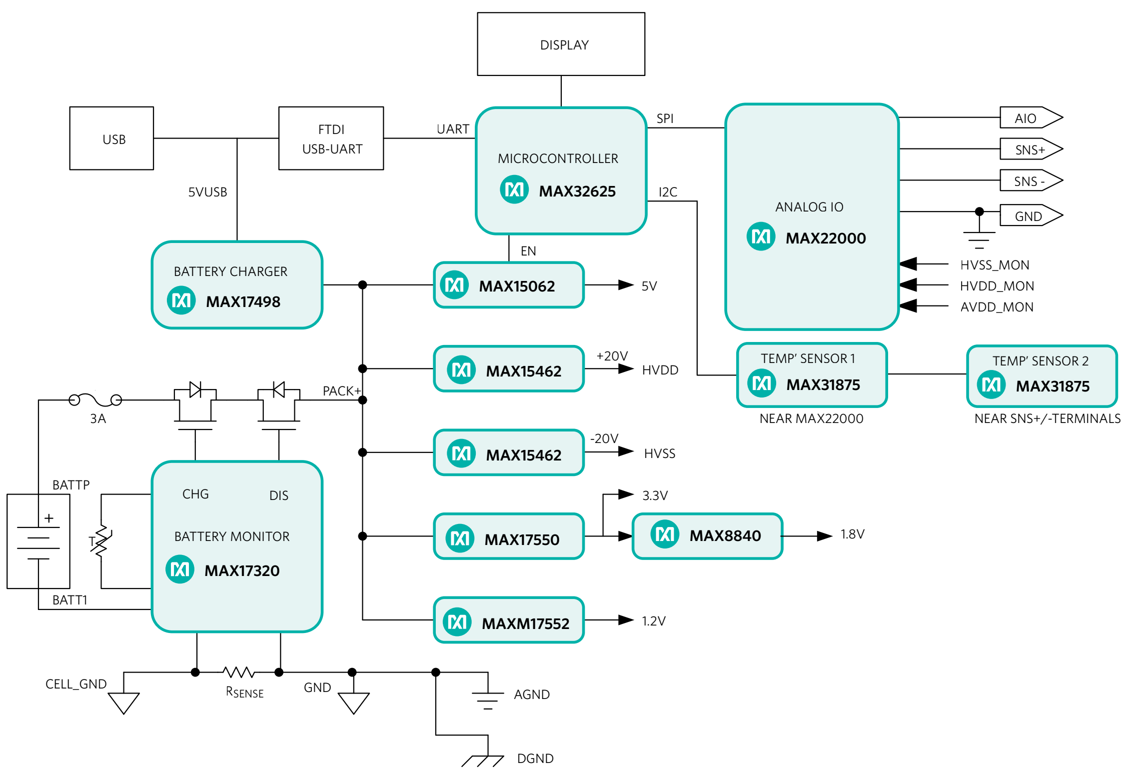


Figure 41. MAXREFDES183# System Block Diagram

MAXREFDES185# High-Accuracy Configurable IO with Safety Monitoring

The **MAXREFDES185#** (**Figure 42**) is a standalone, universal input-output (UIO) reference design that provides safety monitoring for all IO signals. It demonstrates a fully software-configurable universal IO module (analog IO + digital IO on a common pin) using the MAX22000 industrial configurable analog IO IC and the MAX14914A low-leakage digital IO (**Figure 43**). The industry-standard 4-way PCB terminal block includes support for temperature measurement using an RTD or a thermocouple, including built-in cold-junction compensation for thermocouple measurements.

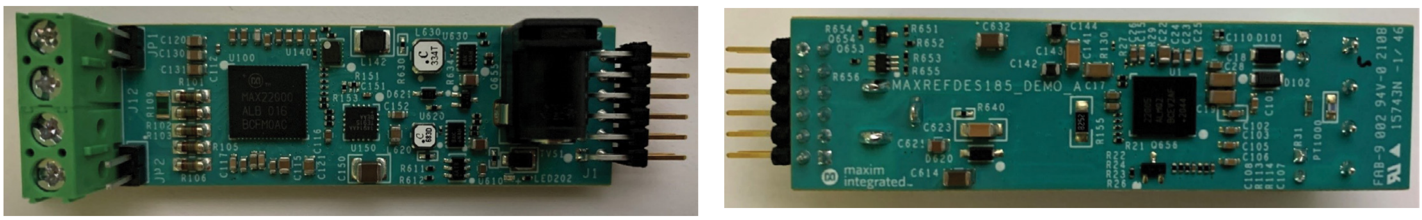


Figure 42. MAXREFDES185# Configurable IO with Safety Monitoring

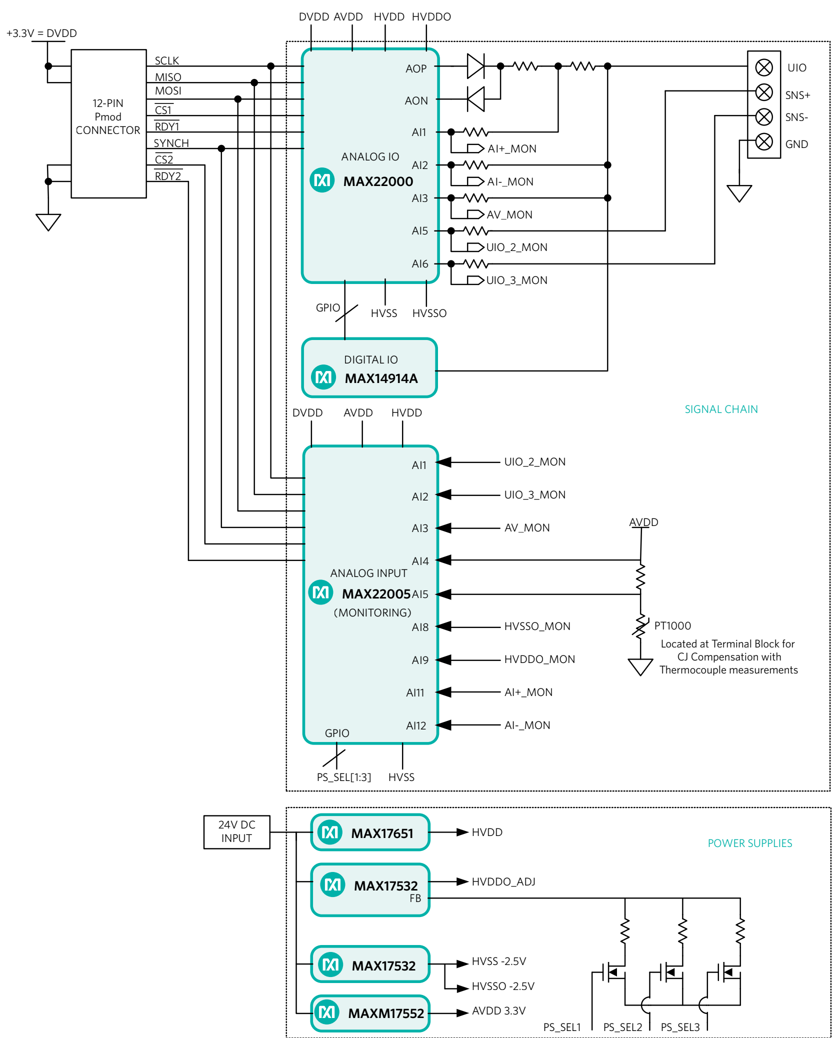


Figure 43. MAXREFDES185# System Block Diagram

Summary of Industrial IO Design Resources

Table 13 and **Table 14** provide an overview of design resources available for both digital IO and analog IO products along with their companion ICs.

Table 13. Design Resources for Digital IO and Companion ICs

Products	Description	Resource Boards
MAX22191	Parasitically powered digital input	MAX22191EVKIT MAX22191PMB
MAX22190	Octal digital input with diagnostics	MAX22190EVKIT MAX22190PMB MAXREFDES176
MAX22199	Octal digital input with serial output	MAX22199EVKIT
MAX22192	Octal digital input with serial output and integrated isolation	MAX22192EVKIT MAXREFDES176# MAXREFDES212#
MAX22195	Octal digital input with parallel output	MAX22195EVKIT
MAX14900E	Octal high-speed high-side switch	MAX14900DEVBRD
MAX14922	High-side switch controller with current limiting	MAX14922EVKIT
MAX14912 MAX14913	Octal high-side switch push-pull driver	MAX14912EVKIT MAX14912PMB MAX14913EVKIT MAXREFDES212#
MAX14915 MAX14916 MAX14917	Octal high-side switch with diagnostics	MAX14915EVKIT MAX14916EVKIT MAX14917EVKIT
MAX14919	Quad-channel low-side switch	MAX14919EVKIT
MAX14914	High-side switch with push-pull driver and digital input configuration	MAX14914EVKIT MAX14914PMB
MAX14906	Quad-channel industrial digital output/digital input	MAX14906EVKIT MAX14906PMB*
MAX14483	6-channel SPI isolator	MAX14483EVKIT USB2GPIOISO
MAX22444 MAX22445 MAX22446	Reinforced four-channel digital isolators	MAX2244XWEVKIT MAX22445FWEVKIT

Table 14. Design Resources for Analog IO and Companion ICs

Products	Description	Resource Boards
MAX22005	12-channel factory-calibrated configurable analog input	MAX22005EVKIT MAX22005PMB* MAXREFDES185#
MAX22007	4-channel 12-bit configurable analog output	MAX22007EVKIT MAX22007PMB*
MAX22000	Industrial-configurable analog IO	MAX22000EVKIT MAXREFDES177# MAXREFDES183# MAXREFDES185# MAXREFDES212#
MAX14001	Single-channel isolated 10-bit ADC with integrated DC-DC	MAX14001EVKIT MAX14001PMB
MAX22530 MAX22531 MAX22532	Field-side self-powered 4-channel 12-bit isolated ADCs	MAX22530EVKIT MAX22531EVKIT

Industrial IO Resources

Webpages

- Industrial I/O
- IO-Link and Binary Drivers
- Isolators and ICs with Integrated Isolation
- Evaluation Boards and Peripheral Modules (Pmods)

Software

- Github Repository for MicroPython Board

Digital IO Application Notes

- Digital Output Drivers: Understanding Key Features and Challenges
- How to Switch Inductive Loads with Demagnetization
- Guidelines to Implement CRC Programming for the MAX14915 Octal, Industrial, High-Side Switch
- CRC Programming for the MAX14900E Octal, High-Speed Industrial Switch
- Selecting the Right N-Channel MOSFET for the MAX14922 For High-Side Industrial Output Applications
- How to Program the MAX14915/MAX14916-8 Channel High-Side Switch
- How to Program the MAX14906 Quad- Channel Industrial Output, Digital Input
- Industrial Digital Inputs with the MAX22191
- Frequently Asked Questions about the MAX22191 Parasitically Powered, Industrial Digital Input
- FAQs: The MAX22190 Octal Industrial Digital Input Device with Diagnostics
- Guidelines to Implement CRC Algorithm for The MAX22190 And MAX22192 Octal Industrial Digital Input with Diagnostics
- Guidelines for Transient Immunity Testing of MAX22190/MAX22192 Industrial Digital Input Serializer

Industrial IO Resources (Continued)

Analog IO Application Notes

- MAX22000 Analog IO Configurations
- Configurable Input/Output Modes for PLC Systems using the MAX22000 and MAX14914A
- How to Program MAX22000 Configurable Analog IO
- Guidelines to Implement CRC Programming for the MAX22000 Configurable Analog IO
- Implementation of Temperature Measurements with the MAX22000
- MAX22005 User Programming Guide
- MAX22005 Universal Analog Input Enables Flexible Industrial Control Systems
- MAX22005 User Calibration Guide
- How to Program the MAX22007 Configurable Analog Output
- Guide to Programming the MAX14001/MAX14002 Isolated ADCs

Design Solutions

- Protect Your High-Side Switch With a Controller that Leaves Nothing to Chance
- Industrial Digital Inputs: They're Not Quite as Simple as Counting from 0 to 1
- Use Configurable Digital IO to Give Your Industrial Controller the Edge
- Worried About Heat in Your I/O Module? No Need to Sweat
- Finally – Digital IO Means Digital IO!
- Give Your Industrial Controller the Edge Using Configurable Digital IO

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Pmod is a trademark of Diligent, Inc.

Learn more

For more information, visit:
www.maximintegrated.com/industrial-io

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